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OPTIMATION, INC.

INSTRUCTION MANUAL

PRECISION AC INSTRUMENTS

OPTIMATION, INC. 7243 atoll ave. north hollywood calif. tr. 7-0222

369.1

PRECISION AC CALIBRATION SOURCE

SINGLE AND TWO PHASE

MODELS AC-101/104/105

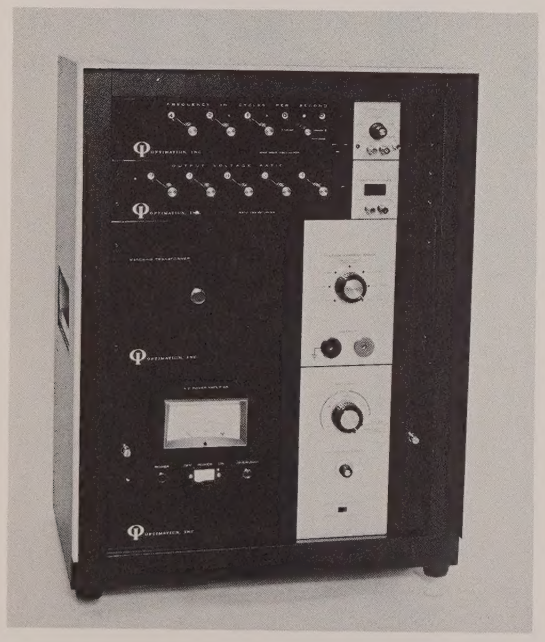
SECTION I

GENERAL INFORMATION

1.1 SCOPE

This publication is the basic handbook of instruction for operation, service and maintenance of all versions of Optimation Models AC-101, AC-104, and AC-105 Laboratory Calibration Sources. It presents a detailed description of the units as follows:

I. General Description and Specifications
II. Installation Information
III. Operating Instructions
IV. Principles of Operation
V. Maintenance
VI. Table of Replaceable Parts



AC 101 with Option 'A'

FIGURE 1-1

1.2 APPLICATIONS

The Laboratory Calibration Source (Figure 1-1) is intended for applications that require the highest degree of amplitude stability, waveform purity, and a wide range of voltages and currents; over the frequency range from 10 to 100,000 Hz, the unit is capable of providing either constant current or constant voltage output selectable from the front panel. The performance characteristics of the source are virtually unaffected by reactive or nonlinear loads.

With its high degree of amplitude stability and ultra low distortion characteristics, the AC-101/104/105 is ideally suited for use as an AC source to calibrate the most accurate and sensitive AC measuring instruments, such as digital and differential voltmeters. Two phase outputs are optionally available to facilitate wattmeter, power factor meter, etc. calibration.

Model AC-104 has at least 1000 volt capability from 35 Hz to 100 kHz. Model AC-101 and 105 have 1000 volt capability from 15 Hz to 30 kHz.

1.3 DESCRIPTION

The basic calibration source consists of a Precision Oscillator, 250 watt Power Amplifier, Matching Transformer, and Power Control panel mounted in a bench cabinet.

A Ratio Transformer is available as Option "A". The Ratio Transformer is mounted in place of the Power Control Panel and connected between the Oscillator and Amplifier to provide precise output voltage steps. After the output has been standardized with a measuring device, such as an AC thermal transfer standard or accurate voltmeter, the Ratio Transformer can be utilized to dial-in voltages or currents within the stability of the source and accuracy of the Ratio Transformer. This feature allows rapid calibration of voltage or current measuring instruments.

Necessary connection provisions for the Ratio Transformer are provided on all models to allow the user to add the Ratio Transformer at a later date if desired.

Two phase output is available with Options "P" or "Q". In these models, the oscillator has two outputs with variable phase angle on phase 2, 0 to 180° leading or lagging. See specifications for detail description. The two phase models are usually furnished in a blower cooled cabinet on casters for ease of mobility (Figure 1-2).

1.3.1 ELECTRICAL DESCRIPTION

The AC-104 Power Source develops a low distortion, highly stable output of 200 VA ±1 db maximum over the frequency range from 45 to 40,000 Hz with extended range from 10 to 100,000 Hz at reduced power. RMS voltages to 1500 volts open circuit and RMS currents to 20 amps are available. At least 1000 volts RMS are available from 35 to 100,000 Hz.

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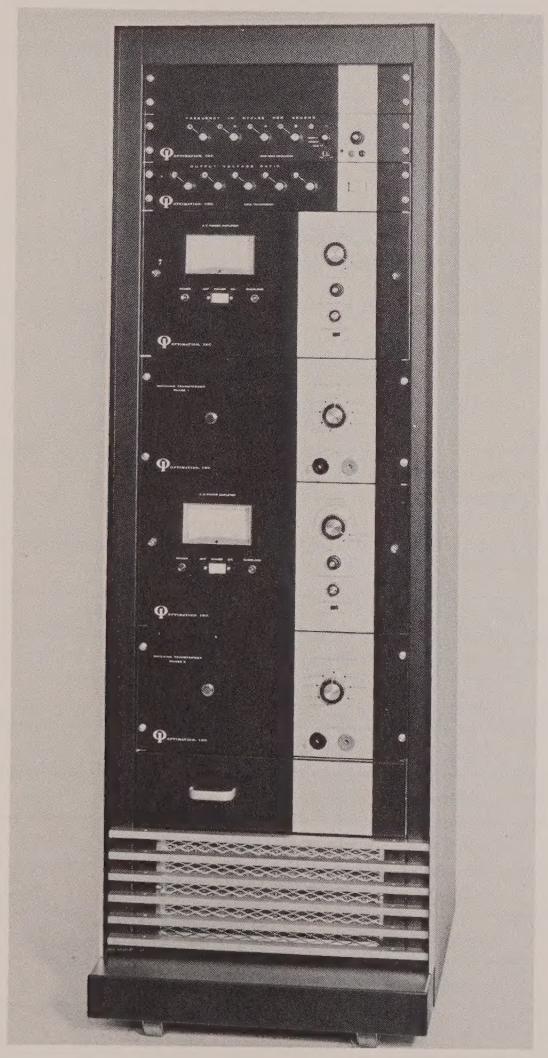
The AC-101 and 105 have 200 VA ±1 db available over the frequency range from 25 to 10,000 Hz with extended range from 10 to 100,000 Hz at reduced power. RMS voltages to 1500 volt open circuit and currents to 20 amp rms are available. At least 1000 v rms is available from 15 to 30,000 Hz.



AC-105 with Options A & Q
FIGURE 1-2

The circuitry (patented and patent pending) employs both tubes and transistors to their best advantage, plus diode rectifiers and Zener diodes. For example, the oscillator utilizes 8 transistors and 1 tube. All DC power supplies are solid state.

The output may be set for matched load impedances from 0.60 ohms to 6000 ohms by means of the VOLTAGE/CURRENT RANGE selector switch located on the Matching Transformer panel. A large plate dissipation reserve permits continuous output with a downward load mismatch as much as 2:1 in the constant VOLTAGE mode. For loads greater than this, the constant CURRENT mode of operation should be utilized. A short circuit load may be applied in the constant CURRENT mode on Models AC-104/105.

OUTPUT REGULATION in the constant VOLTAGE mode is adjustable for zero variation, rated load to open circuit, over a frequency range from 40 to 50,000 Hz (104), 20 to 10,000 Hz (101/105) by means of an Amplifier panel mounted control.

A similar adjustment may be made in the current mode to provide "tight" current regulation (AC-104 and 105 only).

1.3.2 PHYSICAL DESCRIPTION

Physically, the AC-101/104/105 consists of a cabinet containing four rack panels utilizing 26¼ inches of rack space. The four panels are the Oscillator, AC line Power Panel, Amplifier, and Matching Transformer. When the optional Ratio Transformer is included, it is combined with the Power Panel.

Two phase sources with Option "P" have an additional rack panel, an Amplifier, which adds 10½ inches or a total rack space of 36-3/4 inches. With Option Q, there is an additional Amplifier as well as Matching Transformer panel--total rack space 45½ inches. When the second Ratio Transformer, Option A2, is included, an additional 3½ inches of rack space is required.

1.3.3 SPECIFICATIONS

Specifications are listed in Table 1-1. Table 1-2 lists the dimensions and weights of the unit.

TABLE 1-1

SPECIFICATIONS

	AC-101	AC-104	AC-105
FREQUENCY			
Range, basic at 1000 V +	15Hz-30kHz	35Hz-100kHz	15Hz-30kHz
At reduced voltage and specifications	10 to 100,000 Hz		
Calibration Accuracy (in CALIB position), 10 to 100,000 Hz	within 1%		
With Option "B", 10 to 9,999 Hz	within 0.1%		
Variations, 1 hour, constant temperature	100 ppm		
PURITY			
Distortion, at 1000 V RMS, 50 to 5000 Hz	0.05%		
50 to 10,000 Hz	0.1%	0.05%	
Hum and Noise, % rated output	50 ppm		
Modulation, near line frequency	0.05%		
OUTPUT			
Amplitude Instability, (1) 1-2 minutes	50ppm to 10kHz	20ppm to 20kHz	20ppm to 10kHz
1 hr. constant temperature	100 ppm	50 ppm	50 ppm
With 10% line voltage change, load impedance	>100 ohms/volt	100 ppm	
Voltage, maximum, open circuit, 50 to 40,000 Hz	1500 V RMS		
25 to 20,000 Hz	1500 V RMS		1500 V RMS

VOLTAGE/CURRENT METER RANGE	VOLTS, RMS (See Note 2 for frequency range)	MATCHED LOAD IMPEDANCE CONSTANT VOLTAGE ONLY	AMPS, RMS (4) MATCHED LOAD	MAXIMUM CURRENT SHORT CIRCUIT CONSTANT CURRENT ONLY
16V/20A	0 to +10 V	0.6 ohms	18 A	20 A (5)
40V/ 8A	0 to +25 V	3.8 ohms	7.2 A	
80V/ 4A	0 to +50 V	15 ohms	3.6 A	
160V/ 2A	0 to +100 V	60 ohms	1.8 A	
400V/.8A	0 to +250 V	375 ohms	.72 A	
800V/.4A	0 to +500 V	1500 ohms	.36 A	
1600V/.2A	0 to +1000 V	6000 ohms	.18 A	

POWER OUTPUT,(3) 25 to 20,000 Hz	200VA ±10%	200VA ±10%
45 to 40,000 Hz	200VA ±10%	

POWER REQUIREMENTS, 105 to 125 VAC(2), 60 Hz ---------- 840 VA ---------- 960 VA --------- 840 VA ------
Line voltages to 250 VAC and frequencies of 50 or 400 Hz are available.

RATIO TRANSFORMER ACCURACY - AC-101, 105 ---- (10R + 1)ppm 50-3000Hz, (100R + 10)ppm 3000-10,000Hz------
R = Ratio

AC-104 ----(10R + 1)ppm 50-10,000Hz, (100R + 10)ppm 10,000-50,000Hz,
(200R + 20)ppm 100,000Hz

TABLE 1-1 SPECIFICATIONS (Continued)

TWO PHASE, Option P or Q, AC-104, 105

Phase 2 Amplifier, Option P

Voltage, maximum, open circuit, 25 to 20,000 Hz----------0 to 38, 75, or 150 VRMS.
3 taps, selectable by 3 position plug and socket under front panel.

Current, maximum, matched load, 25 to 5,000 Hz----------10 ARMS.

Distortion, 50 to 10,000 Hz, 250 VA ± 10%----------0.05%

Power, 25 to 20,000 Hz----------250 VA ± 10%

Phase 2 Amplifier, Option Q-----Specifications for PURITY and OUTPUT same as Phase 1.

Phase angle, Phase 2 lead or lag Phase 1----------0 to 180°

Phase angle control, 10 turn potentiometer; resolution----------0.02%

Amplitude of Phase 2 varies as a function of phase angle in accordance with the expression $\frac{1}{\sin\theta + \cos\theta}$ where θ is the phase angle. Minimum amplitude occurs at 45° and 135° where it is .707 of that at 0°, 90°, or 180°.

Amplitude control----each phase has a separate amplitude control located on the Oscillator.

POWER REQUIREMENTS, 105 to 125 VAC, 60 Hz----------1800 VA

NOTES:

(1) Amplitude instability specifications are valid after 2½ hours warmup from room temperature. In typical application AC-101/104/105 is left ON continuously, eliminating the warmup period. Unit may be used after a 10 minute warmup with amplitude slowly drifting downward.

Additional warmup time should be allowed when using the AC-101/105 above 10 kHz or the AC-104 above 20 kHz. Above these frequencies, losses in the output transformer causes heating requiring additional time to stabilize the amplitude. (See Section III, Paragraph 3.5 for additional data).

(2) Voltages listed in the table are available from AC-101/105 over the frequency range 15 to 30,000 Hz--from AC-104 over the frequency range 35 to 70,000 Hz (see supplementary Table 3-1 for maximum tap voltages to be used from 70,000 to 100,000 Hz on Model AC-104.

(3) Maximum power output is defined for a line voltage of 117 VRMS. If the line voltage is lower, maximum power will be lower as defined in the equation: $P_{max} = 200 \times \frac{(E_{line})^2}{(117)^2}$

NOTES:

(4) AC-104/105

Currents listed are available when the matched load is connected and the source is operating in the constant voltage mode. In the constant current mode, matched load impedances are lower (see Note 5).

AC-101

Currents listed are available when the matched load is connected with the source operating in either the constant voltage or constant current mode.

(5) AC-104/105

A series resistor built-in between the Amplifier and Matching Transformer in the constant current mode allows extended operation with a short circuit load. Actual matched load for the 16V/20A tap in current mode is 0.1 ohm; 160V/2A tap - 10 ohms; etc. Short circuit permitted 20A tap only.

AC-101

Short circuit loads should not be used for more than a few minutes at a time, at maximum current, and are only permitted on the 16V/20A tap on Model AC-101. Matched load for the 16V/20A tap on Model AC-101 is the same for VOLTAGE or CURRENT Regulation mode 0.6 ohms.

TABLE 1-2

DIMENSIONS AND WEIGHTS

AC-101/104/105 Laboratory Calibration Source

CABINET, overall--------31-3/4" H X 23¼" W X 16" D

PANEL SPACE Utilized----26¼" H X 19" W X 11" D max.

WEIGHT, NET complete----------210 lbs.

WEIGHT, SHIPPING in 4 or 5 containers:

1. Oscillator----------25 lbs.
2. Amplifier----------90 lbs.
3. Matching Transformer----------70 lbs.
4. Cabinet----------100 lbs.
5. Ratio Transformer----------25 lbs.

TOTAL SHIPPING WEIGHT----------310 lbs.

These weights are subject to change.

SECTION II

INSTALLATION

2.1 PACKING AND INSPECTION

2.1.1 UNPACKING

The AC-101/104/105 is normally shipped in four (or five) containers. The Oscillator and Amplifier are shipped in separate two-section "shell-within-a-shell" heavy duty cardboard containers. This is done to minimize the possibility of damage in transit. A third container holds the Matching Transformer. The fourth container holds the cabinet with the line Power Panel mounted in place. If Option "A" is ordered, the Power Panel is omitted and a fifth carton contains the Ratio Transformer.

NOTE

BECAUSE OF THE WEIGHT OF THE AMPLIFIER CHASSIS AND THE MATCHING TRANSFORMER CHASSIS, IT IS RECOMMENDED THAT TWO PERSONS BE USED TO LIFT THEM OUT OF THEIR RESPECTIVE CONTAINERS.

Save all packing materials to simplify repackaging if reshipment should become necessary.

2.1.2 INSPECTION

Inspect each unit for freedom from shipping damage as soon as it is unpacked. In particular, make the following checks:

1. Make sure that no tubes are broken and that all tubes are firmly seated in their sockets. Also, insure that all transistors mounted in heat sinks are firmly seated in their heat sinks - Amplifier and Oscillator. If the inside of Oscillator cannot be seen through vent slots, remove Oscillator cover to inspect.

2. Make sure that all other components are free of apparent physical damage.

3. Check that all knobs are tight on their shafts and that they do not bind when turned. Operate controls and switches and check for smoothness of operation. Any binding or jamming indicates abnormal mechanical operation and should be investigated and corrected before operating the unit. Do not force any controls that do not turn freely or permanent damage may result.

NOTE

THE UNIT IS PACKED FOR SAFE DELIVERY. IF ANY SHIPPING DAMAGE IS FOUND, TAKE IMMEDIATE STEPS TO FILE A DAMAGED SHIPMENT CLAIM WITH THE CARRIER THAT DELIVERED THE INSTRUMENT AND CONSULT WARRANTY STATEMENT AT REAR OF THIS MANUAL.

2.2 INSTALLATION REQUIREMENTS

2.2.1 The AC-101/104/105 Calibration Source requires the space indicated in Figure 2-1.

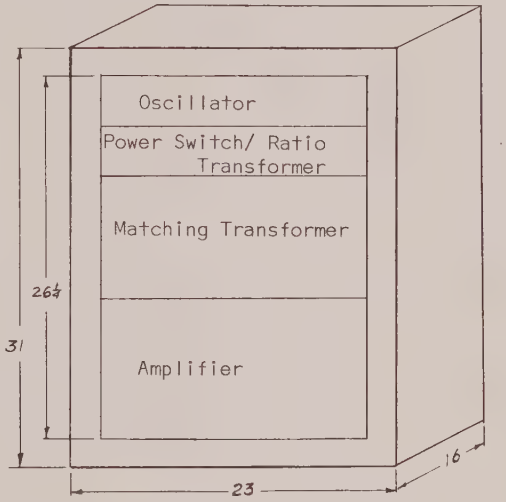


Figure 2-1 Outline Dimensions

To install the Oscillator, Amplifier, and Matching Transformer chassis, it will be easiest if the cabinet is laid flat with the front facing upward. To protect the cabinet, put one of the rubber corner blocks from the packing materials under each corner while cabinet is laid down. The various chassis can then be lowered into place and securely fastened with the mounting screws provided.

The amplifier chassis has a "drop-down" front panel to facilitate access to the underside of the chassis without having to pull the amplifier out of the cabinet. After lowering the amplifier in place in the cabinet, loosen the two thumbscrews on the front panel and raise it upright. This will expose the rack mounting chassis flanges. The amplifier is mounted with eight mounting screws provided. The chassis should be mounted in the cabinet in accordance with Figure 2-1.

NOTE

THE AMPLIFIER MUST BE MOUNTED BELOW THE MATCHING TRANSFORMER AS SHOWN!! A MUFFIN

TYPE FAN IS INSTALLED IN THE CABINET BASE* FOR COOLING OF THE OUTPUT TUBES. ON RACK MOUNTING SYSTEMS, THE FAN IS MOUNTED ON THE AMPLIFIER CHASSIS. IT IS ESSENTIAL TO KEEP THE AREA AROUND THE LOUVERS AND BELOW THE CABINET CLEAR FOR ADEQUATE VENTILATION. THESE LOUVERS PROVIDE AIR EXHAUST FOR THE BLOWER.

* On sources ordered without cabinet, the fan is mounted on the Amplifier itself.

Cabinet may now be raised to an upright position.

2.2.2 AC-104/105 WITH OPTION P OR Q

Normally the AC Source with two-phase Option P or Q is furnished with a cabinet on casters. It is typically shipped via electronic van with all chassis mounted and interconnected.

Figure 2-2 illustrates mounting for an AC-104/105 with Option Q.

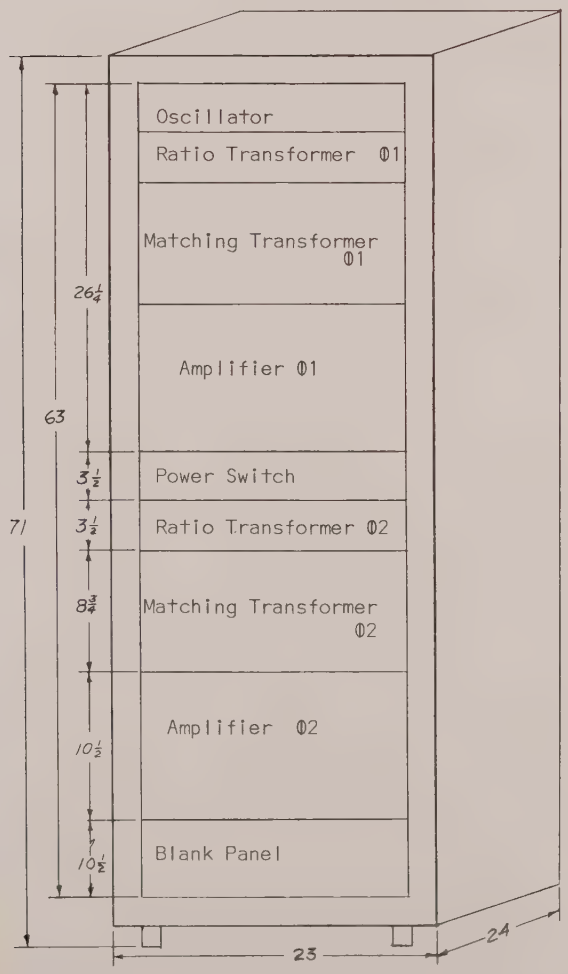


Figure 2-2 Dimensions AC104/105; Options A,A2,Q

It is suggested that the rack mounting placement illustrated be followed if possible. However, it is not essential as long as the AREA DIRECTLY BELOW THE AMPLIFIER IS KEPT CLEAR TO PROVIDE ADEQUATE AIR CIRCULATION FOR THE FAN.

2.2.3 CONNECTING INPUT, OUTPUT AND LINE POWER LEADS.

a. Figure 2-3 shows the rear interconnections for the AC-101/104/105. The shielded GR cable should be connected at one end of the GR connectors on the rear of the Oscillator marked AMP, and at the other end, to the GR connectors on the Amplifier INPUT terminals. On versions with Option "A" Ratio Transformer, this cable should be connected from the OUTPUT terminals of the Ratio Transformer to the Amplifier INPUT terminals.

CAUTION!!

INSURE THAT THE SHIELD SIDE OF THE GR CONNECTOR IS PLUGGED INTO THE BLACK TERMINAL AT EACH END OF THE INPUT CABLE, OTHERWISE THE OUTPUT OF THE OSCILLATOR MAY BE SHORTED TO GROUND.

b. The Amplifier output cable is attached on one end to the Matching Transformer. Plug the locking connector on the other end into the OUTPUT socket on the Amplifier.

c. The meter cable has an RCA plug on one end and is attached at the other end to the Matching Transformer. Plug this cable into the meter receptacle on the Amplifier.

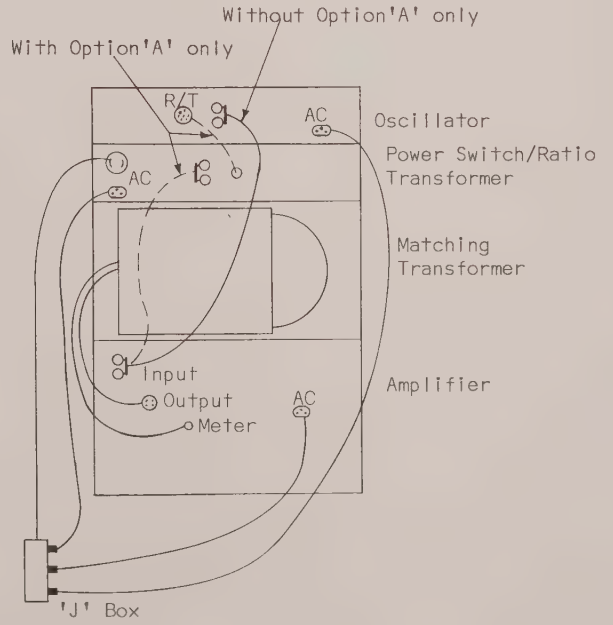


Figure 2-3 Rear Interconnections AC101/104/105

d. Ratio Transformer when furnished. When the optional Ratio Transformer is furnished, a cable with a 5 or 7 pin plug is attached to the Ratio Transformer. Connect this cable in the mating socket provided on the Oscillator.

e. The two pin twist lock plug and cable attached to the cabinet "J" Box, should be plugged into the MASTER POWER SWITCH socket located on the rear of the Ratio Transformer or Master Power Switch panel. This connection permits the four AC receptacles in the "J" Box to be switched by the MASTER POWER SWITCH.

On Sources furnished without the cabinet, a "J" Box assembly with cables attached is furnished. This "J" Box may be mounted in a convenient location in the cabinet in which the AC-101/104/105 is mounted.

The Ratio Transformer, Oscillator and Amplifier line cords should be plugged into these receptacles. When the individual power switches on the Amplifier and Oscillator, respectively, are turned ON, the main POWER switch will control power to each individual chassis.

NOTE: Individual power switches are provided on both the Amplifier and Oscillator so that these units can be operated independently, if desired.

f. Any excess cable length should be fastened down away from items such as the fan, output tubes, etc. Signal cable should be routed separately from the AC line power cords.

2.2.4 INTERCONNECTION FOR AC-104/105 WITH OPTION P OR Q.

a. Figure 2-4 shows the rear interconnections for models with Option P or Q. Interconnections are similar to those described in Paragraph 2.2.3, except as mentioned below.

b. Oscillator has two rear output connectors. Insure that the output marked PHASE A is connected to Phase 1 Amplifier INPUT terminals. Output marked PHASE B should be connected to Phase 2 Amplifier INPUT terminals.

When Option A is furnished, Phase 1 Amplifier INPUT is connected to the Ratio Transformer OUTPUT terminals and NO connection is made to PHASE A output on Oscillator. Cable attached to Option A Ratio Transformer is plugged into mating receptacle marked PHASE A on Oscillator.

When Option A2 is furnished, Phase 2 Amplifier INPUT is connected to Phase 2 Ratio Transformer OUTPUT terminals and NO connection made to PHASE B output on Oscillator. Cable attached to Option A2 Ratio Transformer is plugged into mating connector marked PHASE B on Oscillator.

d. Line power receptacles for the Oscillator, Amplifiers, and Ratio Transformers are provided on the rear of the Master Power Switch panel. A receptacles is also provided for the cabinet fans. Power to these receptacles is controlled by the Master Power Switch.

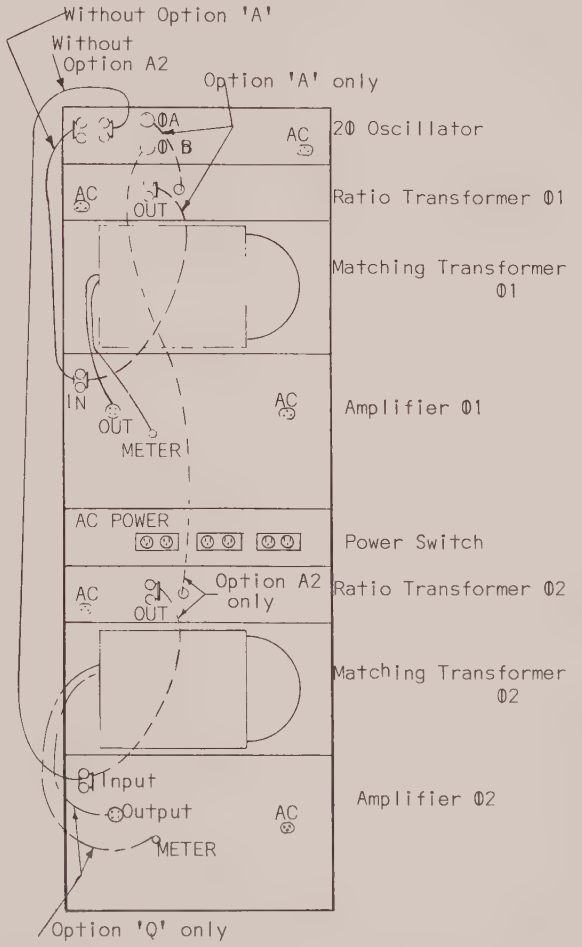


Figure 2-4 Rear Interconnections, with Options P,Q

2.2.5 LENGTH OF OUTPUT LEADS

The length of the output leads is not critical within reasonable limits of 2 or 3 feet. It should be kept in mind, however, that a voltage drop can occur through the leads. If the source is being used in a zero internal resistance condition, the impedance of the leads could be an important factor. For example, a 10 foot length of 16-gauge copper wire would introduce an impedance of approximately 40 milliohms into the output circuit.

No. 12 rubber covered copper wire is adequate for

all operating conditions of the Source with the output selector switch on any tap. No. 18 wire is adequate for operation utilizing switch position taps from 160 volts up.

NOTE: See Section III, Paragraph 3.5 for discussion of output cable for high frequency, high voltage operation.

The output mating connectors furnished with the Matching Transformer chassis are designed for currents up to 50 amps. They are more than adequate in size for the AC-101/104/105.

2.2.6 ELECTRICAL CONNECTIONS

The AC-101/104/105 Laboratory Calibration Source is intended for use with 115 volt 60 Hertz line. Provision for 50 Hertz and/or 230 volt line is optionally available from Optimation.

CAUTION

DO NOT USE 50 Hz LINE FREQUENCY UNLESS SPECIAL 50 Hz POWER TRANSFORMER IS INCLUDED IN EACH AMPLIFIER.

To protect operating personnel, the cabinet, various chassis, and panel should be grounded. This is accomplished when the 3-conductor power cable is plugged into a proper 3-conductor polarized receptacle. The offset pin on the power cable 3-prong plug is the ground pin.

2.3 PREPARATION FOR RESHIPMENT

If reshipment is necessary, the various chassis should be packed in the same containers in which they were received. Use the same packing material if it is available and in good condition.

If original packing is not available, or is in poor condition, each chassis must be packed securely in an inner box. This inner box must be surrounded by a minimum of 2 inches of shock absorbent material and placed in an outer box. This packing procedure minimizes the possibility of shipping damage.

CAUTION

DO NOT ATTEMPT TO SHIP AC-101/104/105 COMPLETE IN THE CABINET. DAMAGE MAY RESULT DUE TO HEAVY TRANSFORMERS. AC CALIBRATION SOURCES SHIPPED IN THE CABINET BECOME THE CUSTOMER'S RESPONSIBILITY!

SECTION III

OPERATION

3.1 GENERAL

The AC-101/104/105 Laboratory Calibration Source has a minimum number of controls and switches and is relatively simple to operate. This section contains general operating instructions and procedures.

3.2 DESCRIPTION OF OPERATING CONTROLS AND INDICATORS.

3.2.1 Figure 3-1 shows the locations of the controls and indicators for AC-101/104/105. Their functions are described below:

a. Oscillator Power Switch

Turns on line power to the Oscillator (Master Power Switch must also be turned on.) Frequency digit indicators and decimal point will light when Oscillator is ON.

b. Frequency Selectors

Select the three (four with Option "B") most significant digits of the desired output frequency. These are displayed in the first 3 (4 with Option "B") digit windows from the left of the Oscillator panel.

c. Frequency Digit Indicators

The digit indicators display the numbers selected by the frequency selectors. The two (one with Option "B") digits to the right are fixed zeros and are utilized to complete the frequency read-out in Hertz.

d. DECADE Frequency Range Selector

Selects one of 4 decade frequency ranges and causes the decimal point to light in the correct place for the respective range selected.

e. Decimal Indicators

Indicate the position of the decimal point according to the frequency range selected by the DECADE frequency selector.

f. VERNIER Frequency Control

Allows a variation of the output frequency by approximately ±1.5% (±0.25% with Option "B") of the nominal value indicated by frequency digit indicators. When the VERNIER Frequency Control is placed in the CALIBrate position (indicated on the panel), it is optimized for best frequency accuracy over the entire frequency range of the Oscillator.

g. Output ATTENUATION, AC-101

The STEP OUTPUT ATTENUATOR has three positions -0db, -20db, -40db.

AC-104/105

The STEP OUTPUT LEVEL control has eleven positions, 0-10, in 10% increments.

h. Output Amplitude VERNIER, AC-101

Provides a continuous variable amount of output ATTENUATION from zero to setting on STEP attenuator. Resolution is 0.002% of full scale. VERNIER is 3 stage Kelvin Varley divider.

AC-104/105

Provides a continuous variable interpolation between adjacent OUTPUT LEVEL steps. VERNIER is 3 stage Kelvin Varley divider. Resolution is $< 0.0005\%$.

i. DC BALance

This is a recessed screwdriver adjustment that permits the DC component on the Oscillator output to be set to essentially zero. See Paragraph 3.6.

j. Oscillator Output Connector

This front panel connector is provided so that the Oscillator output may be obtained direct when it is desired to use the Oscillator separate from the rest of the Source.

k. MASTER POWER Switch

This switch controls power to the Oscillator and Amplifier line cords. With Option "A", Ratio Indicators light when the MASTER POWER Switch is ON.

l. Ratio Indicators (Option "A")

Indicate output ratio selected.

m. Ratio Selectors (Option "A")

Select output ratio 0.0000 to 1.1111.

n. Ratio Transformer OUTPUT Terminals

Provide low distortion, low noise output voltages up to 2.9 V RMS with sufficient power to drive a typical transfer standard. Voltages in the microvolt region are readily

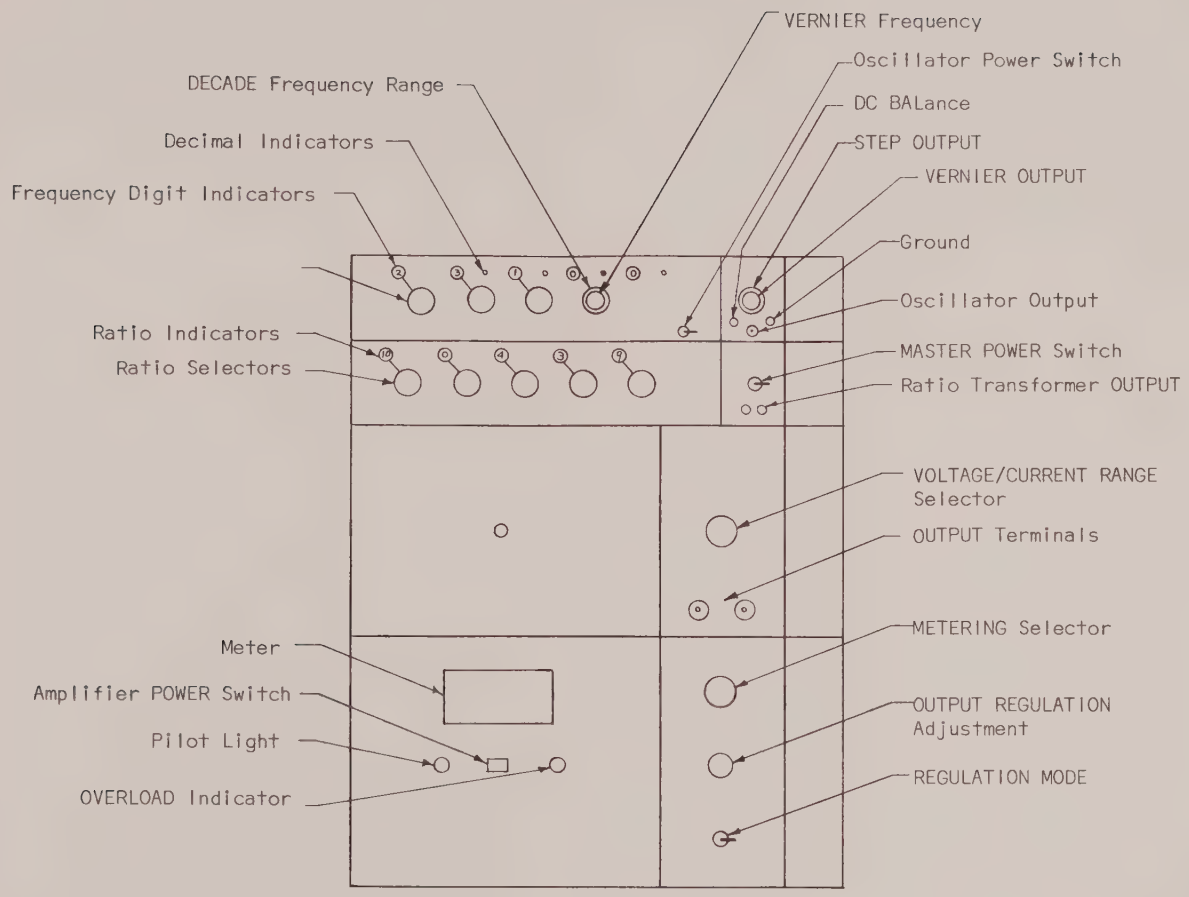


Figure 3-1 Location of Controls and Indicators

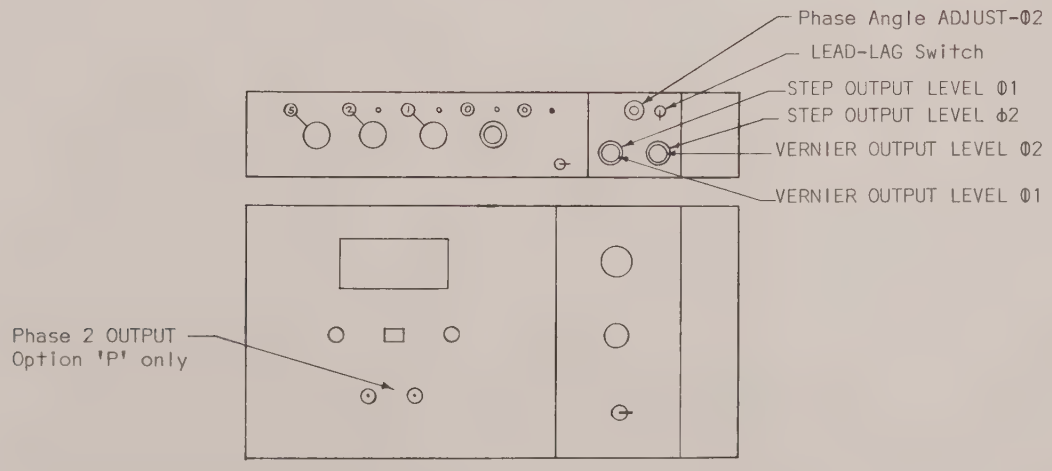


Figure 3-2 Location of Controls and Indicators, Option P or Q

obtainable.

o. METERING Selector Switch

This switch allows selection of TUBE TEST (each of the eight output tubes cathode current), Source OUTPUT VOLTAGE, AMPLIFIER OUTPUT CURRENT (Paragraph 4.4.1f). The latter two in accordance with the VOLTAGE-CURRENT RANGE selected and the respective scale on the meter.

p. Meter

The meter indicates either voltage or current as selected by the METERING selector switch.

q. Amplifier POWER Pilot Light

This light glows when AC power is connected to the Amplifier and the Amplifier Power ON-OFF switch is in the ON position.

r. Amplifier POWER ON-OFF Switch

Turns on line power to the Amplifier (when the MASTER POWER switch is ON).

s. OVERLOAD Indicator

Glows when the Source is being overloaded.

t. OUTPUT REGULATION Adjustment

This adjustment provides the means to set the internal (output) resistance to zero (see Paragraph 3.6.1) for constant voltage operation or internal resistance to near infinity for constant current operation. (See Paragraph 3.6.2 AC-104/105 only).

u. REGULATION MODE

This switch allows selection of either constant VOLTAGE or constant CURRENT regulation.

CAUTION!

DO NOT CHANGE THE POSITION OF THE REGULATION MODE SWITCH BEFORE TURNING THE STEP AND VERNIER AMPLITUDE CONTROLS TO ZERO (COMPLETELY COUNTER-CLOCKWISE).

v. VOLTAGE-CURRENT RANGE Selector

Allows selection of one of seven voltage and/or current ranges. An AMPLIFIER DIRECT (160V/2AMP) position is provided to by-pass the matching transformer.

w. OUTPUT Terminals

The voltage and/or current output of the Source appears at these terminals in accordance with the VOLTAGE-CURRENT RANGE selected and setting of amplitude controls.

3.2.2 Figure 3-2 shows location of controls and indicators for units with Options P or Q that are different or in addition to those on single phase sources.

Additional Controls and Indicators:

a. Phase Angle ADJUST - Ø 2

This control allows phase angle of Phase 2 to be adjusted from 0° to 180° with reference to Phase 1. This 10 turn control has a 10 turn counting dial (uncalibrated) to facilitate accurate resetting and/or phase angle calibration.

b. LEAD-LAG Switch

Allows phase angle of Phase 2 to LEAD or LAG Phase 1.

c. No Output connectors are provided on front of Oscillator. DC Balance control and test jacks are on rear of Oscillator.

d. Phase 2 OUTPUT Terminals (Option P only)

The voltage and/or current output of Phase 2 Amplifier appears at these terminals in accordance with output tap selected and setting of Phase 2 amplitude controls.

e. Phase 2 Output Tap Selector (Option P only)

Under the drop-down Amplifier front panel, a 3-position plug and socket arrangement allows selection of the Phase 2 Amplifier output tap.

f. Amplifier and Matching Transformer controls for Option Q Phase 2 are the same as Phase 1.

3.3 PRELIMINARY PROCEDURES

Before power is applied to the AC-101/104/105 Calibration Source, the operator must set certain controls as outlined in the TURN ON PROCEDURE, Paragraph 3.3.1. It is assumed that the Source has already been installed according to the procedures outlined in Section II.

3.3.1 TURN ON PROCEDURE

1. Set all output amplitude controls STEP and VERNIER to zero - fully counterclockwise.
2. Set all Ratio Transformer Selectors to zero.
3. Place REGULATION MODE Switch in VOLTAGE position. (Both phase Amplifiers Option P and Q).
4. Turn OUTPUT REGULATION control fully counterclockwise. (Both phase Amplifiers Option P and Q).
5. Place METERING Selector Switch to "V6" (each phase Amplifier Option P and Q).
6. Place Oscillator Power Switch ON.

7. Place Amplifier POWER Switch ON (both phase Amplifier Option P and Q).

8. Place Master POWER Switch ON.

   Power is applied to the source and all pilot lights, digit windows and decimal points should light.

9. Set Oscillator frequency to nominal value such as 1000 Hz.

10. Watch Amplifier Meter to see that tube current is normal (both phase Amplifiers Option P or Q).

    There will be an initial surge of tube current indicated when unit is first turned on. This is followed by a return to zero followed by a slow buildup of current to the TUBE TEST range on the Meter.

    When V6 tube current has stabilized in the TEST area, switch to each of the eight tube test positions to verify that each is within the TEST area on the Meter.

    IF ANY TUBE CURRENT REMAINS ABOVE THE TUBE TEST area IMMEDIATELY TURN SOURCE OFF AND CONSULT SECTION V, PARAGRAPH 5.2.1 on output tube balance adjustment. If any tube remains below TUBE TEST area, consult Paragraph 5.2.1.

11. Place METERING Selector Switch to SYSTEM OUTPUT VOLTAGE.

    The AC-101/104/105 is now ready to operate. To meet all stability specifications listed in Table 1-1, a warmup period of 2½ hours from room temperature should be observed. The source may be used after a 10 minute warmup with the amplitude slowly drifting in a downward direction.

3.4 OPERATION

3.4.1 GENERAL

a. After the AC-101/104/105 is turned ON and functioning normally per Paragraph 3.3.1, it may be operated as follows:

   1. Select the desired VOLTAGE/or CURRENT tap. See Table 3-1 for appropriate tap. See Table 3-2, page 17 for taps vs. frequencies.

   2. Select the frequency desired with the frequency selectors and the DECADE frequency range selector. The decimal point will appear in the correct position to read out frequency directly in Hertz.

   3. On Calibration Sources with optional Ratio Transformer,set the Ratio Selectors to 1.0000.

   4. Connect the load desired.

   5. Set the amplitude STEP and VERNIER controls while observing the meter until the desired output is applied to the load. The built in meter is designed only as a monitor for output voltage or current. At frequencies to 10 k Hz, the meter is ±3% accurate increasing to about 30% at 100 k Hz.

b. % Maximum voltage and current as a function of % matched load impedance is shown in Figure 3-3. Values of matched load impedance are listed in Table 3-1.

   Maximum undistorted power as a function of % matched load impedance is shown in Figure 3-4.

3.4.2 VOLTMETER CALIBRATION

The AC-101/104/105 may be used as a stable AC source in the calibration of precision AC voltmeters. When the Ratio Transformer is included, various voltages may be dialed in after an initial calibration eliminating the need to calibrate or measure each voltage. The excellent amplitude stability of the AC-101/104/105 practically eliminates AC-Source-caused digit "rollover" and "needle wander" in digital and differential voltmeters, respectively. To calibrate voltmeters proceed as follows:

a. AC-101/104/105 without Option A (Ratio Transformer)

   1. Select desired frequency.

   2. Select desired voltage tap. See Table 3-1 for appropriate tap. (OUTPUT REGULATION MODE switch to be in VOLTAGE position).

   3. Set METERING Switch to OUTPUT VOLTAGE.

   4. Adjust output voltage to approximate voltage desired using STEP and VERNIER amplitude controls.

   5. Connect meter to be calibrated to Source Output terminals.

   6. Accurately measure Source output voltage by means of an accurate AC voltmeter or thermal transfer standard with DC reference. Readjust STEP and VERNIER amplitude controls for precise voltage desired.

   7. Read voltage indicated on meter under test and compute error.

b. AC-101/104/105 with Option A Ratio Transformer

   1. Select desired frequency.

   2. Select 16V/20A, 160V/2A, or 1600V/.2A tap for voltages to 11.111V, 111.11V, or 1111.1V, respectively. (For frequencies above 70kHz AC-104 or above 30 kHz AC-101/105 consult

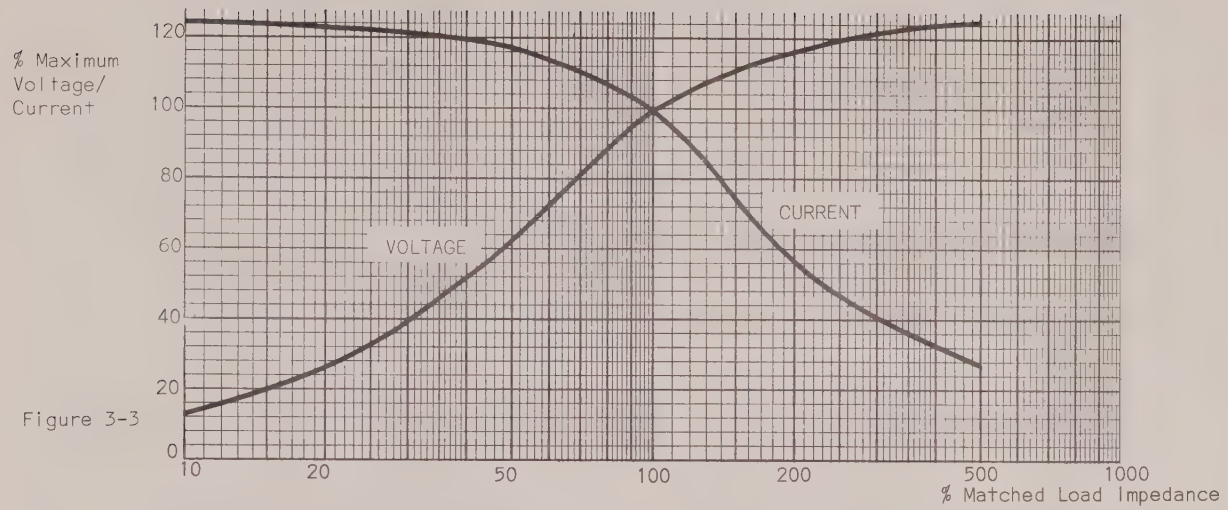


Figure 3-3

TABLE 3-1 Matched Load Impedance--Maximum Voltage-Current

VOLTAGE-CURRENT RANGE TAP	MATCHED LOAD* IMPEDANCE	MAXIMUM UNDISTORTED OUTPUT WITH MATCHED LOAD CONNECTED		MAXIMUM OUTPUT VOLTAGE OPEN CIRCUIT
		VOLTAGE ±5%	CURRENT ±5%	
16V/20A	0.6 ohms	11 V	18 A	15 V
40V/ 8A	3.8 ohms	28 V	7.5 A	38 V
80V/ 4A	15 ohms	56 V	3.7 A	75 V
160V/ 2A	60 ohms	124 V	2 A	150 V
400V/.8A	375 ohms	280 V	.75 A	375 V
800V/.4A	1500 ohms	560 V	.37 A	750 V
1600V/.2A	6000 ohms	1120 V	.18 A	1500 V

* Matched load is defined as that load whose impedance permits maximum power transfer from the AC Source to the Load.

1. Frequency range AC-101/105 - 25 to 20,000 Hz; AC-104 - 50 to 40,000 Hz.

2. For matched load values in constant current mode, AC-104/105, see Note 5, Page 4.

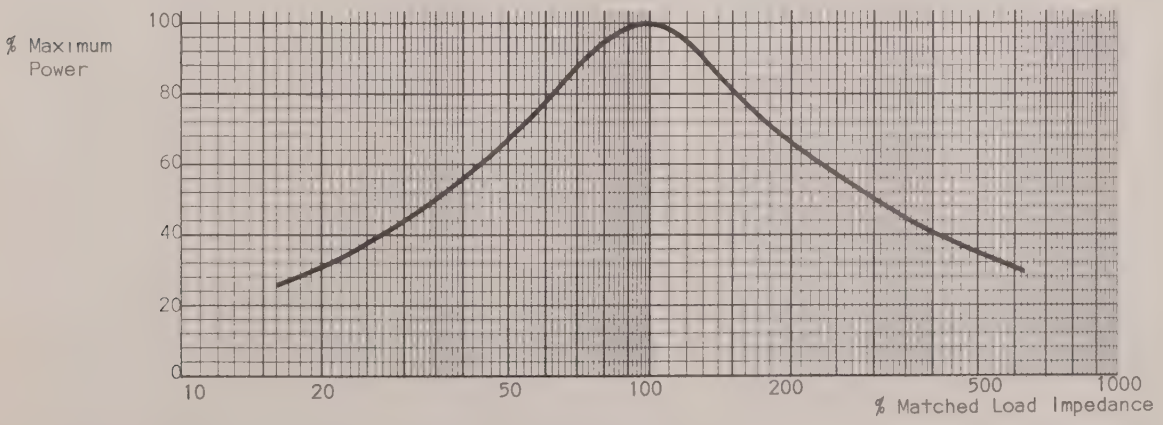


Figure 3-4 %Maximum Power vs. % Matched Load Impedance

Paragraph 3.5 for tap to be used).

3. Set Ratio Transformer Selectors to .50000.

4. Adjust STEP and VERNIER Amplitude controls to obtain precisely 5, 50, or 500 VRMS output, respectively. This is determined by measurement with an external accurate AC voltmeter or thermal transfer standard plus DC reference.

5. Ratio Transformer may now be used to dial-in other voltages without the need for a calibration measurement at each voltage. For example, if the AC-101/104/105 were calibrated at 500 VRMS, a voltage of 1000 VRMS may be obtained by setting the R/T to 1.00000; 995.64 volts by setting R/T to .99564; etc.

   Linearity of the AC-101/104/105 is typically well within 0.02% over a 10:1 voltage range when using the Ratio Transformer to dial-in voltages for frequencies to 10,000 Hz.

6. If the frequency is changed, it will be necessary to readjust the amplitude control.

   NOTE: When calibrating voltmeters whose impedance changes as a function of voltage applied, the OUTPUT REGULATION should be adjusted for zero internal source resistance to obtain the highest degree of accuracy for various Ratio Transformer settings.

   Thermal type voltmeters are an example of this type meter. Their impedance is typically expressed as X ohms/volt (usually in the order of 200 ohms/volt.) At 1000 VRMS, such a meter would represent a load of 200 k ohms, while at 100 VRMS, its load changes to 20 k ohms.

   To set OUTPUT REGULATION to zero internal resistance, follow the procedure outlined in Paragraph 3.6.1

3.4.3 AMMETER CALIBRATION

The AC-101/104/105 may also be used to calibrate ammeters. Currents up to 20A and greater may be obtained from the Source.

a. AC-101/104/105 without Ratio Transformer

   1. Amplitude controls fully counterclockwise for zero output.

   2. Select desired frequency.

   3. Set VOLTAGE-CURRENT RANGE Selector to 16V/20A tap.

   4. Connect load consisting of ammeter to be calibrated in series with standard ammeter or precision shunt.

   5. OUTPUT REGULATION MODE Switch to CURRENT.

   6. Adjust amplitude controls to desired current level as measured by standard ammeter or voltage drop across precision shunt.

   7. Read current indicated on ammeter to be calibrated and compute error.

      NOTE: See Note 5 under Specifications (Page 4) for matched load values. The Source should be operated in the CURRENT mode with a load that is equal to or less than matched load resistance. DO NOT DISCONNECT LOAD IN CURRENT MODE WITHOUT FIRST SETTING AMPLITUDE TO ZERO.

b. AC-101/104/105 with Ratio Transformer

   The Ratio Transformer may be used to dial-in current similar to the method described for voltage.

   1. Amplitude controls set for zero output.

   2. Select desired frequency.

   3. Set VOLTAGE-CURRENT RANGE Selector to 16V/20A tap.

   4. OUTPUT REGULATION MODE Switch to VOLTAGE. (The Source exhibits better current amplitude linearity for various Ratio Transformer settings when operated in the VOLTAGE MODE - see CAUTION below).

   5. Connect load consisting of ammeter to be calibrated in series with standard ammeter or precision shunt.

   6. Set Ratio Transformer to 1.00000.

   7. Adjust STEP and VERNIER amplitude controls to obtain full scale current desired - for example, 10A. (If 20A is used, multiply R/T settings by 2). Standardizing current is indicated on standard ammeter or by voltage drop across precision shunt.

   8. Note full scale error of ammeter being calibrated.

   9. Use Ratio Transformer to "dial-in" other currents. For example, 5A in the above example is obtained at an R/T setting of .50000.

      CAUTION

      DO NOT CONNECT LOW IMPEDANCE AMMETER DIRECTLY ACROSS OUTPUT TERMINALS IN VOLTAGE MODE ON ANY TAP OTHER THAN 16V/20A. When using other taps, a suitable series resistance must be used to insure the maximum downward mismatch does not exceed 2:1 (see Table 3-1 for matched load values).

3.4.4 WATTMETER CALIBRATION, AC-104/105 WITH OPTION P OR Q

Two phase versions of the Source permit calibration of AC wattmeters with an AC signal. In the past, AC wattmeters have usually been calibrated with D.C. Therefore, the method described is intended as a suggestion for wattmeter calibration with AC voltage and current. Wattmeters to 30KW may be calibrated with Option Q (1500V x 20A).

An AC wattmeter has two inputs, a voltage coil and a current coil. The value of power in watts is indicated on the meter and is equal to EI cos θ where θ is the phase angle between the voltage and current. Cos θ is also called the power factor. The wattmeter performs a multiplication as well as a phase angle measuring function. Each of these functions should be calibrated in addition to calibrating meter scale linearity.

Procedure:

1. Amplitude controls for each phase to zero.

2. Phase angle ADJUST - Ø 2 to zero (fully counterclockwise).

3. Select desired frequency.

4. Calculate convenient voltage and current values to provide full scale wattmeter reading.

5. Select desired VOLTAGE and CURRENT taps on each respective phase. (Either phase may be used for voltage or current).

6. REGULATION MODE Switch to VOLTAGE for voltage coil phase and CURRENT for current coil phase (current phase REGULATION MODE switch should be set to VOLTAGE position if Ratio Transformer is used in that phase - see Step 4 of Paragraph 3.4.3 b.

7. LEAD-LAG Switch to LAG.

8. Connect Wattmeter voltage coil to phase output being used for voltage. Connect accurate voltmeter to this output for calibration monitor.

9. Connect Wattmeter current coil to phase output being used for current. Connect accurate ammeter or precision shunt in series with current coil for calibration monitor.

10. Set voltage and current of each phase to values calculated for each respective phase.

    Wattmeter should now read full scale.

11. Check phase angle by varying Phase Angle ADJUST about zero. Angles less than zero or in the fourth quadrant may be obtained by switching LEAD-LAG switch to LEAD. Zero degree phase angle occurs at maximum reading on Wattmeter (cos $0^{\circ} = 1.0$).

    NOTE: Phase angle ADJUST is not calibrated except at $0=0^{\circ}$, $.500=90^{\circ}$, and $1.00=180^{\circ}$. By external phase angle measurement, this control could be calibrated for convenient angles such as 60° where cos $\theta = 0.5$.*

12. "Multiplication accuracy" of Wattmeter may be checked by using a different voltage and current that equals the same power. For example, 50V x 2A, 25V x 4A, 100V x 1A -- all equal 100 Watts.

13. Power factor may be checked on Wattmeter by setting phase angle to 60° *. At this angle, power should be $\frac{1}{2}$; i.e. P = EI cos 60° = EI (0.5). Also at phase angle of 90°, the power will equal zero.

14. Meter scale linearity may be calibrated by varying voltage and/or current and comparing calculated power to power read on Wattmeter.

    Ratio Transformer: When the optional Ratio Transformer is included in either or both phases, Wattmeter scale linearity may be quickly determined by "dialing-in" various voltage and current combinations. The R/T's may be calibrated in a manner similar to that described in Paragraph 3.4.2 b. and 3.4.3 b.

* NOTE: Phase 2 amplitude varies as a function of phase angle ADJUST setting in accordance with $\frac{1}{\cos\theta + \sin\theta}$ where θ equals phase angle. Therefore, at 0°, 90°, and 180°, Phase 2 amplitude equals 1.0. At 45° and 135°, Phase 2 amplitude equals 0.707.

3.5 HIGH FREQUENCY OPERATION (above 20 k Hz AC-101/105 or above 30 k Hz AC-104)

The AC Calibration Source may be used as a voltage calibration source at high frequencies with excellent amplitude stability. The high power output (200 VA) of the AC-101/104/105 make high frequency voltage calibration feasible.

At the higher frequencies, however, additional characteristics of both the source and device under test must be understood and taken into consideration.

a. Capacitive Loading

As frequency goes up, the loading effect of Matching Transformer capacitance increases using additional power from the amplifier. This increased loading at high frequencies causes additional warmup amplitude drift that is not present at lower frequencies. (For detailed discussion of this phenomena, see Paragraph 4.4.3 c.). The operator should allow the AC-101/104/105 additional warmup time (about 20 minutes) when operating the AC-104 at or above

30 k Hz, or the AC-101/105 at or above 20 k Hz.

The magnitude of amplitude change during this additional warmup period increases as frequencay is increased. For example, on Model AC-104, the total amplitude drift after switching to 30 k Hz is in the order of 0.02% during the additional 20 minute warmup. At 100 k Hz, the total amplitude drift will be in the order of 0.5% during the additional warmup period.

This amplitude drift is a slow change in output in one direction. After the additional warmup period, the amplitude becomes quite stable. At 100 k Hz and 1000 V, amplitude stability is in the order of 100 to 200 ppm for 10 to 20 minutes.

b. Output Leads

Due to the increased loading effect capacitance represents at high frequencies, output leads with low and constant capacitance must be utilized.

For example, at 20 k Hz, 1000 VRMS, a load of 1500 pf will require 200 VA. At 100 kHz, 1000 VRMS, it takes 200 VA to drive 300 pf. Note that a change in capacitance of a few pf will represent a considerable change in load. Load regulation may be adjusted to zero to compensate for load change to 10 k Hz on AC-101/105 and 50 k Hz on AC-104. Above these frequencies, however, if the load impedance (capacitance) changes, the output voltage will change. When test leads are moved with relation to each other, their capacitance changes - hence, the need for output leads with constant capacitance.

Twin lead with 300 ohm impedance has 3.4 pf per foot. For lower capacitance, 600 ohm antenna "ladder lead" has 1.7 pf per foot. At the present time, these antenna leads offer a readily available solution to the problem. As accuracy requirements increase above 20 k Hz, new transmission type leads and techniques will have to be developed.

c. Table 3-2 lists the maximum allowable voltages for each Matching Transformer tap at high frequencies. While the AC-101/104/105 is capable of higher voltages than those tabulated in Table 3-2, over dissipation of the output tubes may result if the limits are not observed.

d. Precautions

Extended operation at or near maximum voltages at frequencies above 20 k Hz should be closely monitored to insure operation within power ratings. Table 3-1 lists maximum voltages (100Ω /volt load) for the several output taps. Table 3-2 lists maximum voltages at high frequencies. Also see Figure 3-3.

Prolonged operation at high frequencies tends to shorten output tube life. THE AC-101/104/105 SHOULD NOT BE LEFT SET AT A HIGH FREQUENCY AND HIGH VOLTAGE OVERNIGHT. When calibration work is completed for the day, set amplitude to zero and frequency to lower value, like 1000 Hz. Leaving the Source turned on continuously in this way will not shorten tube life or deteriorate specifications. It also avoids repeating the warmup cycle.

TABLE 3-2
High Frequency Voltage/Tap Limits

	Maximum Allowable Output Voltage	
OUTPUT TAP	AC-101/105 30kHz-50kHz	AC-104 70kHz-100kHz
16V/20A	3.5 V	5 V
40V/ 8A	8 V	15 V
80V/ 4A	20 V	32 V
160V/ 2A	140 V to 50kHz 100 V to 100kHz	140 V
400V/.8A	180 V	200 V
800V/.4A	500 V	500 V
1600V/.2A	1000 V to 40kHz 700 V to 60kHz	1100 V

When using Ratio Transformer to "dial-in" voltage at high frequencies in Table 3-2, the following are recommended taps:

VOLTAGE RANGE	TAP AC-101/104/105
0 - 1.11110 V	R/T Direct
1.11110 V - 11.1110 V	40V/8A
11.1110 V - 111.110 V	160V/2A
111.110 V - 1111.10 V	1600V/.2A

3.6 OPERATING ADJUSTMENTS

3.6.1 CONSTANT VOLTAGE REGULATION

The apparent internal resistance of the AC-101/104/105 may be adjusted to zero by means of the OUTPUT REGULATION Control. This is especially desirable when calibrating (by means of Option A R/T) voltmeters whose impedance varies as a function of input voltage.

a. Procedure:

1. Set REGULATION MODE Switch in VOLTAGE position.

2. Connect a voltmeter across the leads going to the load at the load. (The AC Scource internal meter may be used for this adjustment, but it is best to use an external meter since the built-in meter is not always connected "across" the load (if the output leads have significant impedance. Also, the built-in meter may have insufficient resolution).

3. With the load disconnected, set desired voltage level.

4. Connect the load and adjust the OUTPUT

REGULATION control until the voltmeter indication is the same as with the load connected.

5. Recheck voltage with load connected. When the output voltage is equal, loaded or unloaded, the effective internal resistance of the AC Calibration Source is zero.

b. Thermal Type Voltmeters

When load is a thermal type voltmeter or transfer standard, the load impedance will be less at lower voltages than at higher voltages - hence, the lowest voltage to be used on a particular Matching Transformer tap represents the greatest load or burden. Therefore, the REGULATION adjustment should be made at the lowest voltage to be used on that Matching Transformer tap.

NOTE: The optimum setting for OUTPUT VOLTAGE REGULATION will remain about the same over a frequency range from 100 to 1000 Hz for a particular voltage tap. If the voltage selector is changed to a different tap, or if the frequency range is changed, it may be necessary to readjust the OUTPUT REGULATION control for zero output resistance. If frequencies over 1000 Hz are used, the output resistance will tend to go positive. For frequencies lower than 100 Hz, the output resistance will tend to go negative. Both of these changes in output resistance are with respect to the setting obtained within the frequency range of 100 to 1000 Hz. It is possible to adjust the output resistance to essentially zero for frequencies slightly above 10 kHz for AC-101/105 and 50 kHz for AC-104.

3.6.2 CONSTANT CURRENT REGULATION ADJUSTMENT (AC-104/105 ONLY

The two load conditions for current regulation adjustment are matched load and short circuit.

1. Set Amplitude controls to zero.

2. Set OUTPUT REGULATION control fully counter-clockwise.

3. Set REGULATION MODE switch to CURRENT.

4. Connect an ammeter (20-25A Full Scale) in series with matched load on the 16V/20A tap. (Total load, including ammeter, 0.1 ohm).

5. Adjust amplitude to desired current output.

6. Short out load resistor and observe ammeter.

7. Adjust OUTPUT REGULATION control so that current is equal for matched load or short circuit.

The current adjustment may or may not be at the same OUTPUT REGULATION control setting as the voltage adjustment for equal frequencies.

CAUTION!!

IF CURRENT REGULATION IS SET TO A NEGATIVE VALUE (OUTPUT REGULATION control too far clockwise) AMPLIFIER MAY BECOME UNSTABLE WHEN OUTPUT IS NOT FULLY LOADED. Insure that matched load or greater is connected to the output at all times when operating in the current mode. (For detailed discussion see Paragraph 4.2.4).

3.6.3 DC BALANCE ADJUSTMENT ON OSCILLATOR

This adjustment was made prior to shipment from Optimation. It is an infrequent adjustment.

a. Procedure

1. Amplifier POWER Switch OFF, Oscillator and Master POWER Switches ON.

2. Set frequency to 1000 Hz.

3. Set Amplitude controls for maximum Oscillator output.

4. Monitor Oscillator output connector (DC BALance test jacks on rear of Oscillator with Options P or Q) with DC voltmeter; full scale 1-1½ VDC.

5. If more than a few millivolts DC appear on the output, adjust DC BALance control for "0" DC on output.

SECTION IV

PRINCIPLES OF OPERATION

4.1 INTRODUCTION

This section describes the principles of operation for the AC-101/104/105 AC Calibration Source. To simplify understanding of the Source, the description is presented in two major parts.

1. Over-all functional operation on a block diagram basis.

2. Detailed analysis of each unit that makes up the Source.

It is recommended that any person attempting to adjust or trouble shoot the AC-101/104/105 read and thoroughly understand the material presented in this section before any work is done on the unit.

4.2 OVER-ALL FUNCTIONAL DESCRIPTION

The AC-101/104/105 functional block diagram, Figure 4-1, indicates the major functional units and their interconnection. Basically, the unit consists of an Oscillator with a high resolution output amplitude control which optionally feeds a Ratio Transformer, which can be used to adjust the Oscillator output in precise steps. The Oscillator output drives the Amplifier,which features an extremely constant gain of about 60. The output of the Amplifier is applied to the power Matching Transformer which provides selection of seven different voltage-current ranges. Output is obtained directly from the Amplifier on the 160V/2A position, bypassing the Matching Transformer.

Both the Oscillator and Amplifier have their own individual power supplies.

4.3 OSCILLATOR

Figure 4-2 shows a simplified equivalent circuit for the Oscillator. Basically, the Oscillator consists of a differential amplifier having a highly stable gain of 30 with positive feedback applied through the network of AR1 and R27. Negative feedback is applied through the bridged-T frequency determining network. When the net feedback applied to the amplifier is positive, the unit will oscillate at a frequency where the transmission characteristic is at a minimum and the phase shift is zero for the bridged-T network (see Figure 4-3)

4.3.1 OSCILLATOR CIRCUIT OPERATION

a. When the oscillator is first turned on approximately one-half of the output voltage of the differential amplifier is applied through the positive feedback loop to the input of the amplifier.

b. The negative feedback is approximately one-third of the output amplitude at the frequency of oscillation and remains constant.

c. Since the positive feedback is greater than the negative feedback, the unit will immediately go into oscillation.

d. As AR1 warms up,its resistance value goes up and the positive feedback is reduced. The positive feedback stabilizes at a value slightly above the amount of negative feedback. This explains the slow downward amplitude drift during warmup.

e. AR1 is the stabilizing element and consists of a special designed lamp having a mechanically stable tungsten resistive element in a vacuum. It provides amplitude stabilization for the Oscillator and works as follows:

   If the output amplitude of the Oscillator tends to go up,the voltage across AR1 increases, thereby increasing the filament temperature of AR1, which in turn increases its resistance. This causes the amount of positive feedback applied to the differential amplifier to decrease. The net signal into the differential amplifier is thereby lowered to the original value, thus stabilizing the output amplitude.

   The amplitude stabilization element AR1 is very sensitive and requires very low power to exercise precise amplitude control. Actually, it consumes less than 1/20th of a watt. The precise control of the amplitude stability element, in conjunction with the excellent gain stability of the differential amplifier without feedback, combine to provide the high order of amplitude stability in the Oscillator.

f. The bridged-T frequency determining network has transmission characteristics illustrated in Figure 4-3. At the frequency of oscillation,transmission is at a minimum and phase shift is zero. The ratio of C1 to C2 determines the steepness of the slope of the transmission characteristic. This steepness in part determines the degree to which harmonics are attenuated. The ratio of C1 to C2 is 1:4, an optimum value taking into consideration slope steepness and practical size of capacitors. For example, with the bridged-T network utilized in the Oscillator, the response to the second harmonic of the frequency of oscillation is up 6 db through the bridged-T network. The third harmonic is up 10 db and high order harmonics approach a maximum of around 20 db. Since the bridged-T network is supplying

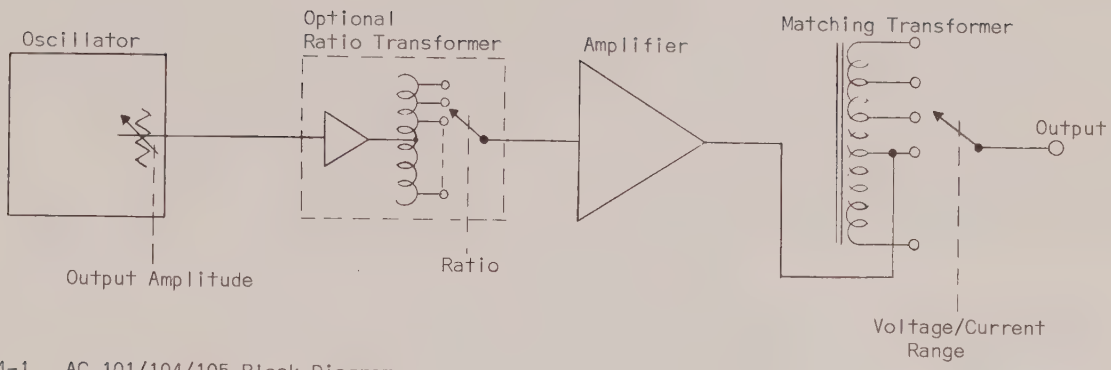


Figure 4-1 AC 101/104/105 Block Diagram

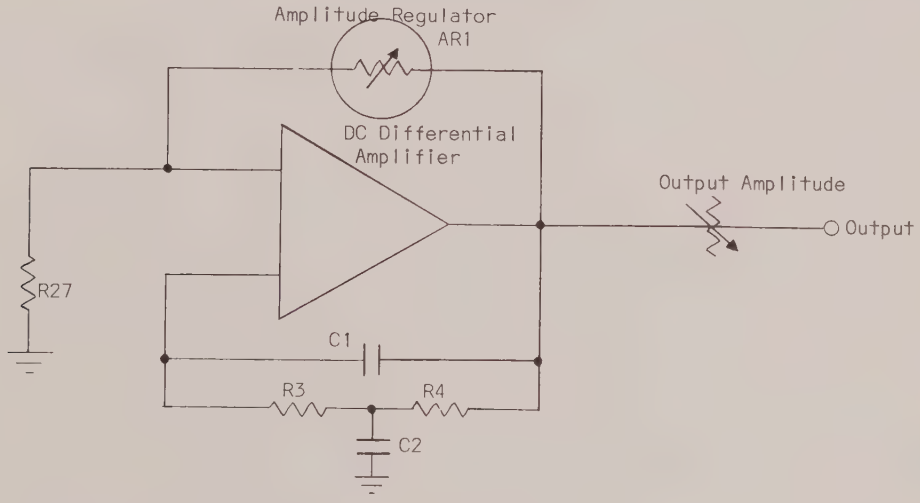
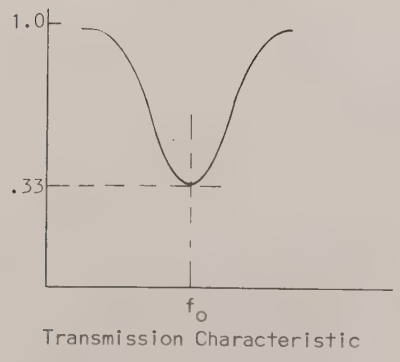


Figure 4-2 Oscillator Equivalent Circuit



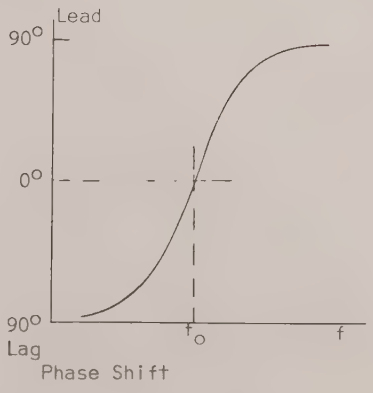


Figure 4-3 Bridged 'T' Characteristics

negative feedback, the distortion due to the second harmonic is reduced by one-half (compared to the amplifier alone); the third to one-third; and high order harmonics to one-tenth of their value in the differential amplifier alone. It is interesting to compare this with the standard Wein bridge oscillator which typically uses a capacitor ratio of 1:1. The 1:1 ratio means that the Wein bridge has a lower equivalent Q factor and, therefore, does not have the distortion reducing properties of the 4:1 bridged-T. Hence, in general, for a particular differential amplifier, the distortion of the Wein bridge oscillator will be higher.

4.3.2 OSCILLATOR CIRCUIT DESCRIPTION

Figure 4-4 shows a more detailed functional block diagram of the Oscillator. In following this discussion, it will be useful to refer to the schematic diagram of the Oscillator at the rear of this handbook.

The differential amplifier basically is contained in V1,a dual triode. Q1 is utilized to provide a constant source of cathode current to V1. Q2 supplies a constant source of plate current to V1A. Looking at Q1 and Q2, V1 sees a very high impedance. Hence, the current from Q1 and Q2 is constant. In this configuration, the gain of the differential amplifier approximates the mu of the tube which is about 30. This gain remains constant over a wide range of external parameters. Since the mu of the tube is determined primarily by the spacing of the elements within the tube, the gain remains fixed. This circuit is unique and the subject of a pending patent.

One side of the differential amplifier input is driven by the bridged-T network supplying negative feedback. The other side of the differential amplifier is driven through the amplitude stability regulator which supplies positive feedback.

The output impedance of V1 is relatively high. This is reduced to a low value by the impedance changing action of Q3 and Q4, a cascaded transistor power output stage connected in an emitter follower configuration. The output impedance of this impedance changer is near zero.

The excellent frequency stability of the Oscillator is in part due to this near zero output impedance and the nearly infinite input impedance of differential stage V1 effectively isolating the bridged-T network.

Q5 is a constant current source for Q3 and Q4.

To minimize the recovery time when switching frequencies, diodes CR-17 and 18 are utilized. As the frequency is switched, the output amplitude tends to rise. Due to the thermal time lag of the amplitude stability regulator, it takes a number of cycles before the amplitude is stabilized. In order to minimize the time required for the signal to restabilize, these diode clippers are set approximately 5 per cent above the nominal output amplitude. When the signal attempts to rise due to switching frequency, it is clipped by the diodes, thus allowing the amplitude stability regulator to "catch up". At high frequencies, the recovery time is a fraction of a second. At low frequencies, it will be in the order of one to two seconds.

The power supply provides all voltages necessary for proper Oscillator operation. The power supplies are extremely well regulated and the circuitry insures good isolation from line voltage variations. DC on the tube filament insures freedom from line beat.

The Oscillator in Model AC-101 has a step attenuator with three fixed steps. For vernier control the Oscillator features a high resolution, three decade potentiometer. This potentiometer has (on a single shaft) a coarse, medium, and fine adjustment in a Kelvin Varley configuration.

Models AC-104/105 have an eleven position step amplitude control. The vernier control is a high resolution three decade potentiometer that interpolates between adjacent steps on the step control.

4.3.3 TWO PHASE OSCILLATOR-OPTION P OR Q (AC-104/105 ONLY)

Figure 4-5 illustrates the method used to generate the two-phase output for Oscillators furnished in Sources having Option "P" or "Q".

The basic Oscillator circuit is the same as single phase units.

The signal at the junction of R3 and R4 lags the main output signal by 45°. This phase angle is determined by the ratio of C1:C2. Since this ratio remains constant as a function of frequency, the phase angle remains constant as a function of frequency.

A portion of phase one output is mixed with this 45° lagging signal and fed into A2 (a differential amplifier) in the correct proportion to provide a 90° lagging signal out of A2. This 90° signal is applied to the center tap of R65, phase angle adjust 10 turn potentiometer.

One end of R5 is connected to the 180° phase shifted signal from T2. The other end of R65 is connected to the 0° phase output from T2.

R65 provides the means to vary phase two output from 0° to 180° as related to phase one. The lead-lag switch allows phase two to either lead or lag phase one by the phase angle set by R65.

The amplitude of phase two varies as a function of phase angle in accordance with the expression $\frac{1}{\sin\theta + \cos\theta}$.
Output amplitude controls are separate and

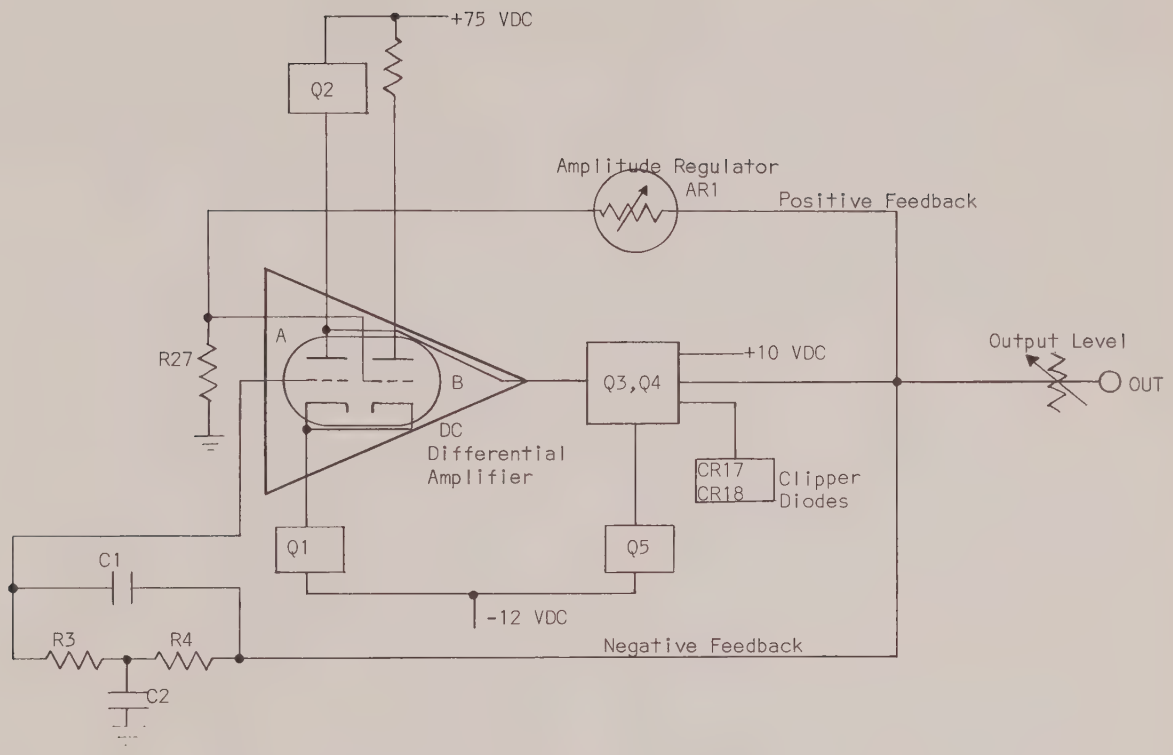


Figure 4-4 Detailed Oscillator Block Diagram

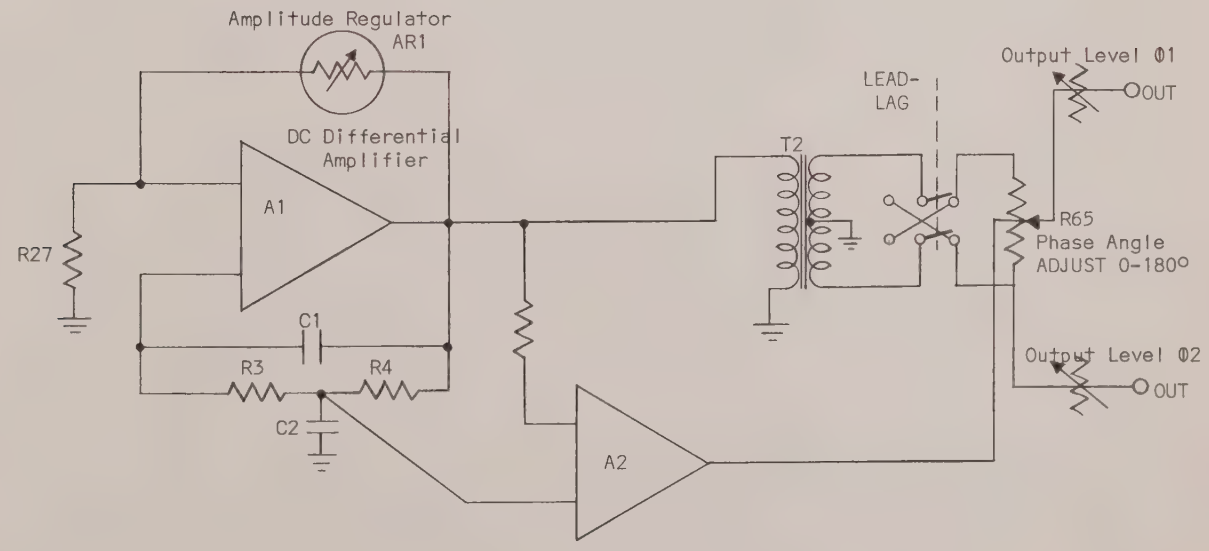


Figure 4-5 Two Phase Oscillator Block Diagram, Option 'P' or 'Q'

identical for each phase. They are the same as used on the single phase calibration Source.

4.4 AMPLIFIER

This paragraph describes the principles of operation of the Amplifier used in the AC-101/104/105. The basic difference between the AC-104 and AC-101/105 Amplifier is the high frequency output transformer in the AC-104.

The amplifier functional block diagram, Figure 4-6, indicates the major functional blocks and their interconnections. The incoming source signal is applied to input stages V1A and Q1, which drive phase inverter-driver stages V2 and V3, which in turn drive the push-pull output stages V8, V10, V12, and V13 (one-half), and V6, V7, V9, and V11 (the other half). Coupling capacitors are only employed between the phase-inverter-driver V2 and V3 and the push-pull output stage. The other stages are direct coupled. In addition to the main signal path just described, various feedback paths are provided. Also included in the Amplifier are a metering circuit, overload indicator, and power supply. The basic functions of each block are described in the following paragraphs.

4.4.1 AMPLIFIER CIRCUIT DESCRIPTION

a. Input Stages V1A and Q1

The Oscillator signal is applied to input stage V1A (half of a dual triode) through a voltage divider. V1 is directly coupled to Q1, which is connected in the emitter-follower configuration. The two stages together provide an impedance-changing function with extremely high input impedance and a low impedance at the output of Q1. This low-impedance output is applied through summing resistor R30 to both V2 and V3.

b. Cathode Follower V1B and Emitter-Follower Q2

A feedback signal, proportional to either output voltage or output current, is applied to the input of cathode follower V1B. The output of V1B drives emitter-follower Q2. Like V1A and Q1, the V1B-Q2 combination also performs an impedance-changing function. The combination V1B-Q2 functions for the feedback signal in a similar manner to the way that V1A-Q1 functions for the source signal. The output of Q2 is applied through summing resistor R29 to both V2 and V3.

c. Phase Inverter-Driver Stages V2 and V3.

Stages V2 and V3 each contain a triode and pentode in one envelope. For these stages, the triode is the input section and is directly coupled to the pentode section. V2 is driven so no phase inversion of the source signal occurs. However, the feedback signal (Z_a and Z_b) applied at R29 (summing point) is inverted. Conversely, V3 is driven so the source signal is inverted and the feedback signal (Z_c and Z_d) applied at R30 (other summing point) is not inverted. Thus, V2 and V3 provide the necessary out-of-phase signals to drive the push-pull output stage. In addition, V2 and V3 peripherial circuitry is arranged so the gain of each combination triode-pentode stage is very nearly equal to the amplification factor of the triode section of the tube. The result is that V2 and V3 each produces a large amount of gain and each has a relatively high input impedance and a low output impedance, thereby, providing an ideal driving source for the push-pull output stage. This circuit is unique and patented.

d. Output Stage

The push-pull signal from V2 and V3 is capacitively coupled to the input of the push-pull output stage consisting of parallel-connected V6, V7, V9, and V11 in push-pull with parallel-connected V8, V10, V12, and V13. The outputs of these tubes are connected in a conventional manner to the output transformer T1.

e. Feedback Loops

Several feedback loops are incorporated in the Amplifier. These were necessarily mentioned only briefly in the previous paragraphs and their functions will now be described in somewhat greater detail.

(1) Overall Negative Feedback

Overall negative feedback voltage is obtained from either the tertiary winding on T2 (constant-voltage mode) or by the voltage drop across current sensing resistance R_C in series with the output (constant-current mode). The overall negative feedback is applied as the input signal to V1B.

The choice of overall negative feedback is made by means of switch S3, REGULATION MODE Selector Switch, which determines whether the amplifier is operating in the constant current or constant voltage mode. In other words, the source of overall negative feedback determines whether the amplifier operates in the constant voltage or constant current mode.

(2) OUTPUT REGULATION Adjustment

R103 is provided (front panel OUTPUT REGULATION control) to adjust the amount of overall feedback so that the amplifier may operate with essentially 100% regulation in either the voltage or current (AC-104/105 only) modes.

Voltage Mode

In the voltage mode, overall negative feed-

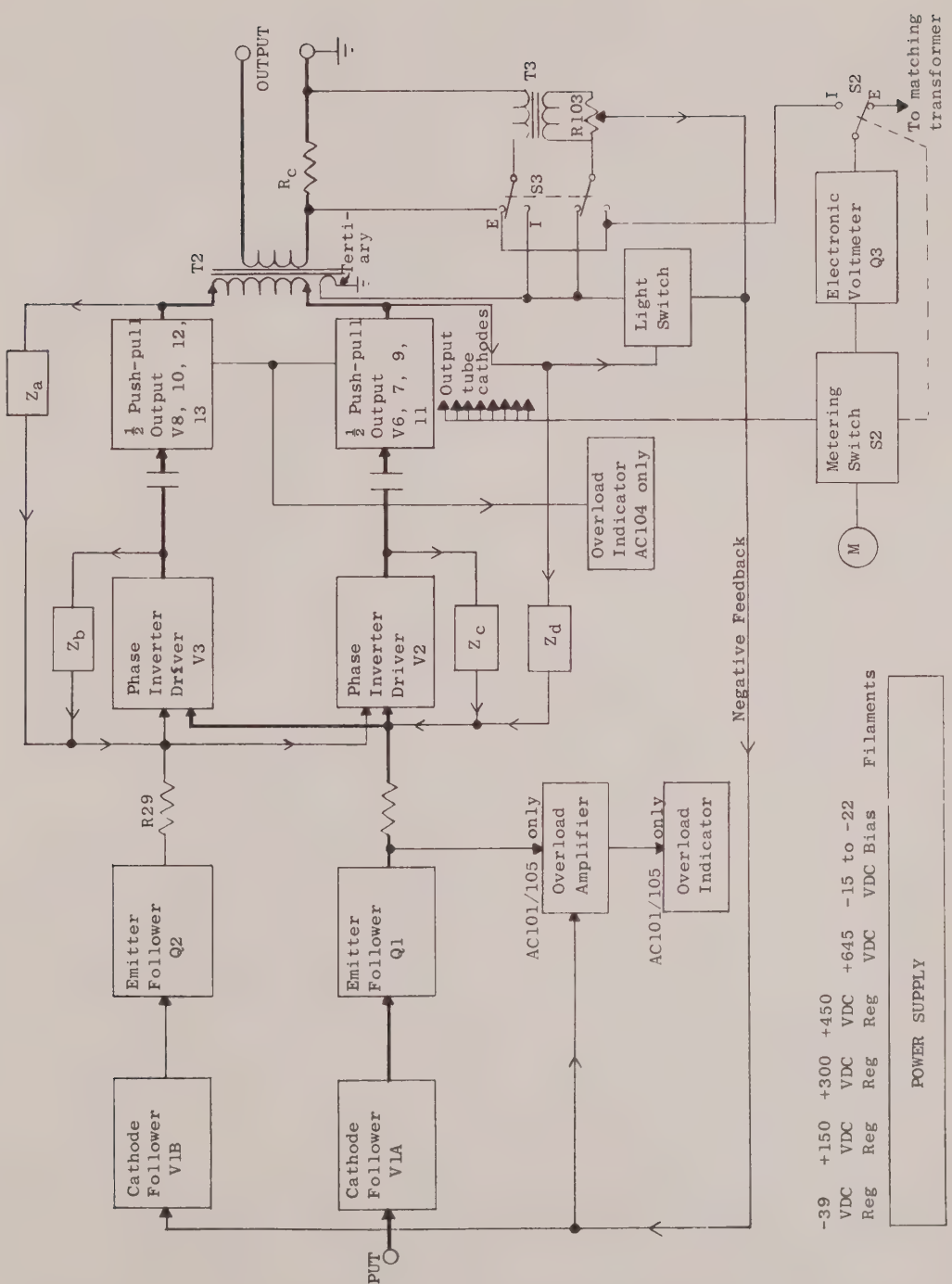


Figure 4-6 Amplifier Block Diagram

back is obtained from the tertiary winding on T2 and is proportional to the voltage on the primary on T2. This negative voltage feedback is summed with positive feedback, developed across T3, a phase inverting transformer. This positive feedback is proportional to current through R_C. It is adjusted in magnitude by means of R103, OUTPUT REGULATION control on the front panel. This control provides a means to adjust the feedback so that the internal resistance of the amplifier is essentially zero. After R103 is adjusted for maximum voltage regulation, the amplifier will compensate for changing load resistance and maintain a constant voltage output.

The amount of positive feedback varies directly as the load; i.e., at no-load positive feedback is zero and there is no voltage drop across the output current sensing resistor R_C. As the load is applied, a voltage is developed across R_C which increases as the load is increased. This, in turn, provides an increasing amount of positive feedback summed with the negative feedback,reducing the overall negative feedback, allowing the Amplifier output to increase; thus, compensating for the output voltage drop due to DC resistance of the output transformer secondary and/or output leads.

Adjustment of R103 (see Paragraph 3.6.1) remains relatively constant from 100 to 1000 Hz. At higher frequencies, the reactive component of T2's impedance increases, necessitating an increase in positive feedback for "zero" internal impedance (adjust R103 clockwise). The amplifier, in the voltage mode, basically has zero internal resistance. Therefore, it is only necessary to compensate for the loss due to the DC resistance of T2 secondary. This is a relatively small amount of positive feedback. Sufficient positive feedback adjustment range is provided in the amplifier to compensate for losses in the output and matching transformer to frequencies in the order of 10 kHz (AC-101/105) and 40 kHz (AC-104).

Current Mode

In the current mode of operation, overall negative feedback voltage is developed by the voltage drop through current sensing resistor R_C. This, in effect, is negative current feedback since the magnitude of voltage fed back is proportional to the load current.

The negative voltage feedback thus developed is summed with positive voltage feedback developed across T3 from the tertiary winding of T1. The magnitude of positive voltage feedback is adjustable by R103 to obtain optimum current regulation (internal amplifier impedance essentially infinite).

The amplifier should not be operated in the current mode with less than matched load connected. The negative feedback in the current mode decreases with decreasing load (increasing load resistance) which tends to make the amplifier less stable. When the load is disconnected in the current mode, there is no negative voltage feedback developed, since there is no voltage drop across the current sensing resistor R_C. The amplifier would then become unstable and oscillate. To prevent this to a certain extent, negative feedback loops Z_a and Z_b are provided from the primary of the output transformer to the phase inverter drivers. While these additional negative feedback loops do tend to prevent unstable amplifier operation, it is possible for the amplifier to become unstable if the OUTPUT REGULATION control (R103) is advanced too far clockwise with no load or lighter than matched load connected. (OUTPUT REGULATION control effective in current mode Models AC-104/105 only).

Current regulation operates as follows:

If the load resistance is decreased, the current through R_C tends to increase;thus increasing the negative voltage feedback and providing the desired reduction of output voltage to maintain a constant current. However, this reduction is not sufficient to maintain completely constant current. Therefore, it is necessary to reduce the positive voltage feedback (obtained from T3 - notice that T3 is across the tertiary winding of T2 in the current mode). This positive voltage feedback is also reduced when the output voltage is reduced,further decreasing the output voltage. Proper adjustment (R103) of this positive voltage feedback will provide optimum current regulation. In the current mode, the amplifier can be adjusted for near infinite internal impedance (100% current regulation) to frequencies of about 3 kHz. (AC-104/105 only - Model AC-101 has fixed current regulation of approximately 3%).

Overvoltage Protection (in AC-104/105 only)

Light Switch LS-101 is provided to protect the amplifier from overvoltage should the load be inadvertently removed in the current mode. In case of accidental load removal, the light switch will automatically switch the amplifier to the constant voltage mode of operation. This light switch senses the voltage applied to the primary of T2. When this voltage exceeds a magnitude such that the output voltage is higher than 160 V, the switch will actuate. This

switch consists of a light source and a photocell. The threshold at which the overvoltage protection will occur is adjustable by trimmer R175. (For adjustment procedure, see Paragraph 5.2.5).

(3) Additional Feedback Loops

Local positive feedback is applied (separately) around stages V2 and V3 to increase the open-loop gain and, thereby increase the advantage (low distortion and low output impedance) gained from the overall negative feedback. The amount of this positive feedback is controlled by a positive feedback adjusting network in conjunction with Z_a, Z_b, Z_c, and Z_d (Z_a, Z_b, Z_c, and Z_d are R-C networks). Additional negative feedback is provided from the plates of the output tubes through Z_a and Z_d back to the summing resistors R29 and R30, respectively. This feedback compensates for the loss or reduction of overall negative feedback that would result with no load or use of a relatively high-impedance load when the Amplifier is operating in the constant-current mode. This additional negative feedback also provides the major portion of negative feedback above 100 kHz; thus preventing high frequency oscillation.

f. Electronic Voltmeter and METERING Switch S3.

The electronic voltmeter amplifier stage Q3 in conjunction with METERING switch S3 provides a rectified voltage to Meter M1. When the METERING switch is in the OUTPUT VOLTAGE or AMP. OUTPUT CURRENT position, a signal proportional respectively to the AC-101/104/105 output voltage or amplifier output current is applied to the input of Q3. The signal is amplified by Q3, rectified by two diodes, and applied to Meter M1. Linear response of M1 is obtained by connection of the diodes in the feedback loop of Q3. METERING switch S3 has eight additional positions to measure the cathode current of each respective output tube, V6 through V13, as a check for tube balance and aging.

The reason that the meter reads AMPlifier OUTPUT CURRENT and not the Source output current (above 2 kHz, AC-101/105; above 10 kHz, AC-104) is that the matching transformer itself starts drawing significant capacitive current at the higher frequencies. Therefore, the meter reading includes load current added vectorially to the capacitive current of the matching transformer.

g. Overload Circuit V4, V5 (AC-101/105 only)

The overload indicator is arranged so a visual signal is given to the operator if the distortion becomes greater than approximately $\frac{1}{4}$ per cent at mid-frequencies. This is accomplished by applying a portion of the overall feedback signal (voltage - or current-derived) and a nominally equal amount of the source signal to V4 (a duo-triode) in such a way that the two signals tend to cancel each other. If the feedback signal contains frequency components that were not present in the source signal (i.e., distortion), this difference signal is amplified by V4 and applied to V5, a self-indicating thyratron. The signal applied to V5 causes this tube to ionize and a glow appears in the overload indicator on the front panel.

h. Overload Indicator (AC-104 only)

One of the four lamps protecting the output tubes from excessive screen current is mounted behind an indicating jewel on the Amplifier front panel. When excessive screen current is drawn, the light glows, indicating an overload condition.

i. Power Supply

The Power Supply provides two separate filament supplies; one completely balanced to ground; regulated DC voltages of +450, +300, +150 and -39 volts; bias voltages of -12 to -22 volts; and +645 volts. Only solid state semi-conductor rectifiers are used in the power supply.

4.4.2 PHASE 2 AMPLIFIER, OPTION "P"

The Power Amplifier for Phase 2 has similar circuitry to that of Phase 1. The primary difference is the Phase 2 amplifier has three output taps selectable by means of a plug and socket arrangement located under the front panel.

There are two versions of Phase 2 Amplifier - Models PA-1027 and PA-1028.

PA-1028

Model PA-1028 has output taps with open circuit voltage ranges of 0-37, 75, and 150 VRMS and maximum current ranges of 0-10, 5, and 2.5 ARMS.

PA-1027

Model PA-1027 is available on special order and has output taps with open circuit voltage ranges of 0-9, 18, and 36 VRMS. Corresponding maximum current ranges are 0-30, 16, and 8 ARMS.

4.4.3 MISCELLANEOUS AC-101/104/105 DATA

a. Maximum Power Output

When operating directly from the Amplifier (160V/2A tap), the maximum power output of the AC-101/104/105 is 250VA. When operating through the Matching Transformer, the maximum power output is 200VA. Maximum power output is specified for a line voltage of 117 VAC or greater; i.e., Max. Power, $P_a = 200 \frac{(E\ line)^2}{(117)^2}$.

Therefore, if the line voltage falls below 117 V, the maximum available power is reduced in accordance with the above expression. As long as the maximum power utilized is equal to or less than P_a for a particular line voltage, the output is not affected by line changes (see specifications in Table 1-1).

b. Constant CURRENT Mode Distortion

At low frequencies, distortion can be somewhat higher in the constant current mode through the Matching Transformer.

In the constant current mode, the Amplifier looks like a high impedance source to the Matching Transformer. The magnetization current of the Transformer is nonlinear. Its magnitude is inversely proportional to frequency. Therefore, the distortion is higher at low frequencies due to the introduction of these nonlinear transformer parameters. This phenomena occurs primarily at frequencies below 100 Hz.

c. High Frequency Amplitude Change

When the source is initially set to a high frequency (>30 kHz, AC-104; >20 kHz, AC-105), the amplitude will drift in one direction, usually down, for a period of time before stabilizing. This assumes the AC-101/104/105 had been warmed up for at least 2½ hours at some lower frequency.

This drift is due to a change in DC resistance of the amplifier output transformer caused by heating under load. (Capacitance of the output and matching transformers represent an increasing load as frequency goes up). At lower frequencies, the DC resistance also changes somewhat with load, but there is sufficient overall negative feedback to compensate for this.

In order to maintain a suitable margin of amplifier stability, the open-loop gain and overall negative feedback are reduced at higher frequencies. Therefore, at higher frequencies the feedback cannot completely compensate for the change in output transformer resistance. As soon as the temperature of the transformer stabilizes, the AC-101/104/105 amplitude will stabilize.

SECTION V

MAINTENANCE

5.1 CALIBRATION PROCEDURES, OSCILLATOR

5.1.1 AMPLITUDE CALIBRATION, AC-101/104/105

The Oscillator will operate for long periods of time without the need to adjust amplitude flatness. To check amplitude flatness of the Oscillator, it is necessary to utilize an AC voltmeter with a frequency flatness of 0.1% or better from 10 to 10,000 Hz. Accurate AC differential or digital voltmeters with high input impedance are suitable instruments.

A separate amplitude adjustment trimmer is provided for each decade frequency range. The trimmers are located as shown in Figure 5-1. If the Oscillator amplitude flatness is not within ±0.5%, it can be adjusted as follows:

1. Set the frequency to 1,000 Hz.
2. Set the VERNIER Frequency Control to the CALIBrate position.
3. Set the output AMPLITUDE VERNIER and STEP control for maximum output.
4. Adjust DC BALance per Paragraph 3.6.3.
5. Adjust R47 until the output voltage is precisely 2.9 VRMS.
6. Set the frequency to 100 Hz and adjust trimmer R44 in a similar manner for precisely 2.9 VRMS.
7. Set the output frequency to 90 Hz and adjust R17 in a similar manner to precisely 2.9 VRMS.
8. The amplitude adjustment for the 10,000 Hz range is made in conjunction with the frequency calibration - Steps 9 through 15 in Paragraph 5.1.2A.

5.1.2 FREQUENCY CALIBRATION

A. Three Digit Models

Normally, the Oscillator will operate for long periods of time without deterioration of frequency accuracy. To determine if the Oscillator is within the specification of ±1%, make the following checks:

1. Monitor the Output with a frequency counter.

NOTE: At the higher frequencies, the test cable capacitance and input capacitance of the counter may load the Oscillator, causing erroneous voltage measurements. To prevent this, insert a 75 pf capacitor in series with the signal (high) side of the line at the oscillator output terminal.

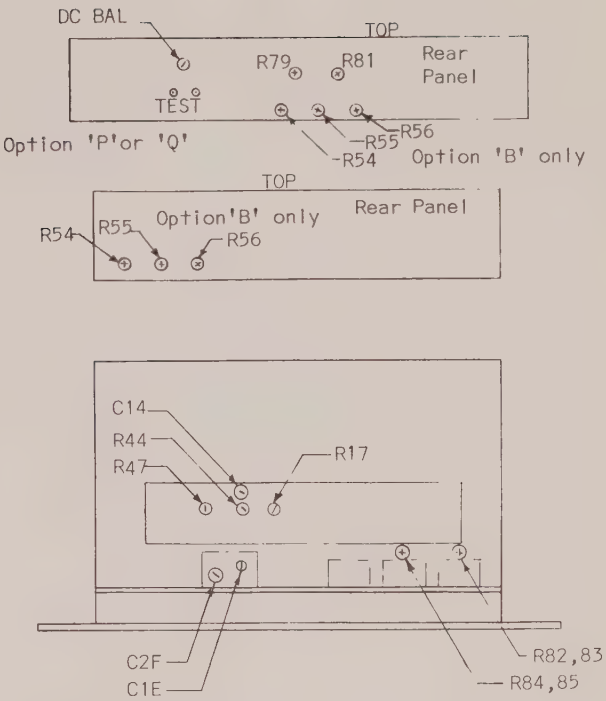


Figure 5-1 Oscillator Adjustment Trimmers

2. Set the VERNIER Frequency Control to the CALIBrate position.
3. Check the frequency at 10,100,1000, and 10,000 Hz utilizing the DECADE Frequency Range Selector. This test verifies the range-to-range tracking.

   If the above frequencies are all within the specificationof ±1%, the Oscillator is within calibration specification.

   If each of the four ranges are within ±1% of each other, but are all either higher or lower than 1% from the nominal frequency, the VERNIER Frequency Control needs to be reindexed as follows:

4. Set the VERNIER control so that the four frequencies of 10,100, 1000, and 10,000 Hz are within ±1% as indicated on the external frequency monitor.
5. Loosen the set screws on the VERNIER Frequency Control knob taking care not to rotate the shaft.
6. When the set screws are loosened, rotate the knob so that the slot is opposite the

CALIBrate position.

7. Retighten the set screws.

8. Recheck the ranges to insure that the shaft hasn't moved during this procedure.

9. If the fourth decade frequency range at 10,000 Hz is not within ±1%, it will be necessary to adjust Trimmers C1E and C2F located on the frequency range DECADE selector switch (see Figure 5-1). Adjust as follows:

10. In addition to the counter, monitor the output with an amplitude measuring instrument that will not appreciably load the Oscillator output. (See note above re: 75 pf series capacitor).

11. Set frequency to 10,000 Hz.

12. Adjust C2F until frequency is exactly 10,000 Hz.

13. Check amplitude for 2.9 VRMS. If not correct, adjust C1E to bring amplitude to 2.9 VRMS.

14. Recheck frequency for 10,000 Hz and readjust C2F, if necessary, to obtain 10,000 Hz.

15. Continue to adjust C2F and C1E as above until optimum setting is obtained for best accuracy of frequency and amplitude. The points occur at the same time.

NOTE: C1E and C2F are interacting because the frequency is determined by their product and the amplitude by their ratio.

16. Set frequency to 90,000 Hz.

17. Adjust C14 until frequency is exactly 90,000 Hz (amplitude at 90,000 Hz may be down 5%).

18. Reset frequency to 10,000 Hz.

19. Readjust C1E and C2F, if necessary, per Steps 9 through 15.

NOTES: 1. Be sure that the VERNIER Frequency Control is in the CALIBrate position when making these adjustments.

2. The period mode of the counter should be utilized for frequencies below 10,000 Hz.

3. To check frequency digit tracking, see Paragraph 5.1.2 C.

B. FOUR DIGIT MODELS (Option "B")

AC-101/104/105's with Option "B" are calibrated so that the output frequency will be within ± 0.1% of the dialed-in frequency of 10 - 9999 Hz. To test this, it is necessary to utilize a counter having an internal crystal reference with a stability of at least one part in 100,000 and an accuracy of better than one part in 10,000. Counters utilizing line frequency as a reference are not suitable for calibration of this Oscillator and should not be used. To check the frequency calibration, proceed as follows:

1. Set the VERNIER Frequency Control to the CALIBrate position.

2. Check 10, 100, 1000, and 10,000 Hz utilizing the DECADE Frequency Range Selector. (At 10,100, and 1000 Hz, use the period mode of the counter). The frequency of the Oscillator should be within ±0.1% of these four dialed-in frequencies. If they are within ±0.1% of each other, but are all either higher or lower than 0.1% from indicated frequency, the VERNIER Frequency Control needs to be reindexed. Loosen set screws on knob and reindex for best accuracy for the four ranges. (0.3% accuracy for 10,000 Hz).

3. After VERNIER is indexed, each range can be individually adjusted as follows:

4. Set the Oscillator to 90 Hz (again use the period mode of the counter). If 90 Hz (11,111.1 μ sec period) is not within 0.1%, adjust R54 (see Figure 5-1) for exactly 11,111.1 μ sec.

5. Set the Oscillator to 100 Hz (10,000 μ sec period). If 100 Hz is not within 0.1%, adjust R55 for exactly 10,000 μ sec.

6. Set the Oscillator to (1,111.11 μ sec period) 900 Hz. If 900 Hz is not within 0.1%, it will be necessary to adjust R82 and R83 simultaneously. This adjustment is necessary very seldom and if made, must be done in accordance with this procedure. R82 and R83 are mounted back-to-back. To adjust them simultaneously, use a long flat bladed screwdriver that engages both potentiometers. They are adjusted for 900 Hz (1,111.11 μ sec). Amplitude flatness is affected if they are not adjusted together.

7. Reset Oscillator to 100 Hz and readjust R55, if necessary, for 10,000 μ sec.

8. Set Oscillator to 1000 Hz (1000 μ sec period). If 1000 Hz is not within 0.1%, adjust R56 for exactly 1000 μ sec.

9. Set Oscillator to 1900 Hz (526.316 μ sec period). If 1900 Hz is not within 0.1%, it will be necessary to adjust R84 and R85 simultaneously. It is essential to adjust these trimmers simultaneously in a similar manner to that described in

Step 6. Adjust for 526.316 µsec.

10. Reset Oscillator to 1000 Hz and readjust R56, if necessary, for 1000 µsec.

11. If the fourth decade frequency range at 10,000 Hz is not within ±0.3%, it will be necessary to adjust Trimmers C1E and C2F located on the frequency range DECADE selector switch (see Figure 5-1). Adjust as follows:

12. In addition to the counter, monitor the output with an amplitude measuring instrument that will not appreciably load the oscillator output. (See Note under Step 1, Paragraph 5.1.2 A., re: 75 pf series capacitor).

13. Set frequency to 10,000 Hz.

14. Adjust C2F until frequency is exactly 10,000 Hz.

15. Check amplitude for 2.9 VRMS. If not correct, adjust C1E to bring amplitude to 2.9 VRMS.

16. Recheck frequency for 10,000 Hz and readjust C2F, if necessary, to obtain 10,000 Hz.

17. Continue to adjust C2F and C1E as above until optimum setting is obtained for best accuracy of frequency and amplitude. The points occur at the same time.

NOTE: C1E and C2F are interacting because the frequency is determined by their product and the amplitude by their ratio.

18. Set frequency to 90,000 Hz.

19. Adjust C14 until frequency is exactly 90,000 Hz (amplitude at 90,000 Hz may be down 5%).

20. Reset frequency to 10,000 Hz.

21. Readjust C1E and C2F, if necessary, per Steps 11 through 17.

NOTES: 1. Be sure that the VERNIER Frequency Control is in the CALIBrate position when making these adjustments.

2. The period mode of the counter should be utilized for frequencies below 1000 Hz.

3. To check frequency digit tracking, see Paragraph 5.1.2 C.

C. FREQUENCY DIGIT TRACKING

Both three and four digit models. Check the tracking of the Frequency Selectors as follows:

1. Set the frequency at 1000 Hz.

2. Check tracking of the most significant Frequency Selector by switching from 1000 to 9000 Hz in 1000 Hz steps.

3. Reset to 1000 Hz and check the second Frequency Selector by switching from 1000 to 1900 Hz in 100 Hz steps.

4. Check the tracking of the third Frequency Selector by switching from 1010 to 1090 Hz in 10 Hz steps.

5. With "B" option only. Check the tracking of the fourth Frequency Selector by switching from 1001 to 1009 in 1 Hz steps.

The procedure outlined in C. above will check all resistors in the bridged-T frequency determining network. There are no individual adjustments for these resistors. If significant errors exist that put the unit out of specification, it is indicative of a malfunction of one of the switch wafers. Check to see that the switch contacts and wiper are free of foreign material.

In the case of Option B, tracking in the first two significant digits may be adjusted to some extent. See Steps 6, 7, 9, and 10 under Option "B" frequency calibration Paragraph 5.1.2 B.

5.1.3 TWO PHASE CALIBRATION SOURCES, OPTION P OR Q

A. AMPLITUDE CALIBRATION

Amplitude calibration for two phase Oscillators is the same as that outlined in Paragraph 5.1.1 except amplitude will be 2.5 VRMS instead of 2.9 V.

Amplitude to be monitored from phase 1 output.

B. FREQUENCY CALIBRATION

Frequency calibration for two phase Oscillators is the same as that outlined in Paragraph 5.1.2 except amplitude will be 2.5 VRMS instead of 2.9 V. Monitor frequency from phase 1.

C. PHASE ANGLE CALIBRATION

The phase adjustment trimmers R79 and R81 (see Figure 5-1) should not require adjustment over long periods of time. The phase calibration procedure may have to be performed if vacuum tube V2 is changed.

Procedure:

1. Set Phase Angle ADJUST to mid-point, 0.500 exactly, as indicated by the 10 turn counting dial. This should correspond to 90° phase angle.

2. Monitor each phase output with an AC voltmeter having at least 0.1% accuracy and high input impedance (to avoid loading the oscillator output). Digital or differential voltmeters with sufficient accuracy are

suitable.

3. Set frequency to 1000 Hz.

4. Set output AMPLITUDE controls for maximum output (2.5 VRMS).

NOTE: It is helpful to monitor phase 1 and phase 2 output on the "X" and "Y" axis, respectively, of an oscilloscope. At 90° phase angle, the resulting Lissajous pattern will be a perfect circle. (Sensitivity of "X" and "Y" axis must be equal).

5. Adjust R79 and R81 until phase 2 output is equal to phase 1 - both 2.5 VRMS and phase angle is exactly 90°.

R79 and R81 are interacting - however, R79 primarily varies amplitude while R81 primarily varies phase angle.

5.2 AMPLIFIER ADJUSTMENTS

5.2.1 OUTPUT PLATE CURRENT BALANCE

For maximum power output at lowest distortion, the cathode current of each output tube should be about the same value. The METERING switch includes eight positions to permit the meter to indicate each output tube current individually. To check the balance of the output tubes, proceed as follows:

1. Make sure that the VERNIER output amplitude control is at zero (fully counterclockwise). Set METERING switch to V6.

2. Turn POWER switch ON and allow one minute for warm-up.

3. Observe meter indication with METERING switch at V6. While still observing meter indication, turn METERING switch successively to V7 through V13. Each output tube, V6 through V13, should indicate cathode current within the TEST area on the meter scale. To read cathode current directly in milliamps, use the meter scale with a full scale reading of 80. The tube currents will run between 20 and 40 milliamps. If the current of V8, 10, 12, or 13 is higher than 40 milliamps (the limit of the meter TEST area) adjust R18, (See Figure 5-2), until the highest tube current is no higher than 40 milliamps. If the current of V6, 7, 9, or 11 is higher than 40 ma adjust R150 in a similar manner. It is permissible for the current of a tube to be slightly below 20 milliamps, but if the current of one tube is considerably below that of the others, the tube should be replaced and R18 or R150, respectively, readjusted until the currents of all tubes are closely matched within the TEST area on the meter.

4. Output Tube Replacement

Each output tube has been aged for a minimum of 200 hours and graded. To insure optimum performance, order output tube replacements from Optimation or our local representative. When individual tubes are ordered, be sure to specify the grade number located on top of the tube.

Output tubes may be replaced in sets of eight. In this case, it is not necessary to specify grade number. However, when output tubes are replaced in a set, it will be necessary to adjust R18 and R150 as above.

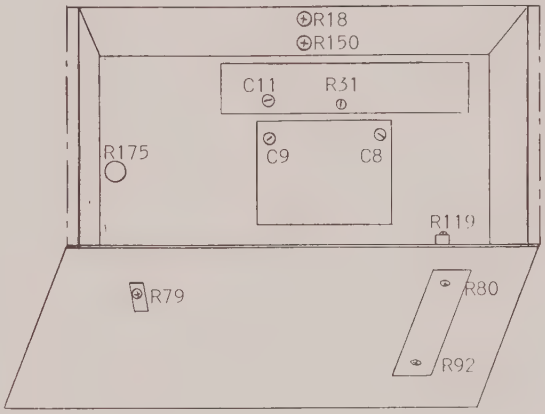


Figure 5-2 Amplifier Adjustment Trimmers

5.2.2 DISTORTION ADJUSTMENTS

The amplifier has been carefully adjusted for minimum distortion at the factory. It will retain its low distortion characteristics for long periods of time due to the nature of the circuitry. Should the distortion of the AC-104/105 increase, FIRST OF ALL CHECK DC BALANCE ON OSCILLATOR (See Paragraph 3.6.3).

When driver tubes V2 and V3 are changed*, distortion trimmers should be adjusted as outlined below:

* These tubes V2 and V3 must be replaced as a matched pair. Order from Optimation or our local representative P/N 550026.

If it becomes necessary to adjust the Amplifier distortion, there are several trimmers available to adjust for minimum distortion at various frequencies. For location, see Figure 5-2 above.

a. R31 (on pre-amp board) adjusts the local positive feedback around the phase inverter Stage V2 and V3.

b. C8 and C9 (on main board) adjust the magnitude and ratio of balanced high frequency negative

feedback from the output tube plates to the signal and feedback summing junction.

. C11 (on pre-amp board) is a high frequency adjustment for local positive feedback around V2.

. R119 (on chassis) (AC-104) or R119b (on chassis) (AC-105) provide an adjustment to minimize second harmonic distortion at high frequencies (balance of output transformer). It is made originally at Optimation and will probably not have to be changed unless the output transformer is changed

A. LOW FREQUENCY DISTORTION ADJUSTMENTS

1. OUTPUT AMPLITUDE controls to zero.

2. Set VOLTAGE/CURRENT RANGE Selector to 160V/2A tap.

3. Connect 60 ohm load.

NOTE: The load resistor utilized, when measuring or adjusting distortion on the AC-104/105, must have a low voltage coefficient of resistance; i.e., a linear relationship between voltage and current.

If it is nonlinear, the load current will be nonlinear with respect to voltage and the current will have a nonsinusoidal waveform. Under conditions where the amplifier exhibits a finite internal impedance, Z_S, a voltage drop is developed across Z_S by the load current. If the load current is nonsinusoidal, harmonic voltages are developed across Z_S and appear in part across the load and indicate erroneously as amplifier distortion.

4. The Output REGULATION adjustment (R103 front panel control) should be set fully counterclockwise.

5. Put the REGULATION MODE switch in the CURRENT position.

6. Set the frequency at 1000 Hz.

7. Monitor the output with a distortion measuring instrument and scope (see Figure 5-3).

8. Set the output for 110 volts.

9. Adjust R31 for minimum distortion. Typical value is 0.02%.

NOTE: Due to the inherent very low distortion of the AC-101/104/105, this adjustment can be facilitated by turning R18 and R150 all the way down (CCW) - minimum plate current - to increase the distortion magnitude. After R31 is adjusted, reset R18 and R150 per Paragraph 5.2.1.

10. Set OUTPUT AMPLITUDE controls to zero.

B. HIGH FREQUENCY DISTORTION ADJUSTMENT, 20 kHz

1. Set frequency to 20,000 Hz.

2. Amplifier should still be in CURRENT REGULATION MODE with 60 ohm load connected.

3. Set the output voltage for 104 V, AC-101/105; or 110 V, AC-104.

4. Set C8 and C9 for maximum capacitance - plates fully meshed.

5. Adjust C8 or C9 for minimum distortion. If trimmer being adjusted (C8 or C9) increases distortion, return it to fully meshed plates position and adjust the other trimmer (C9 or C8).

NOTE: C8 and C9 interact. There are several settings of C8 and C9 that provide minimum distortion. Adjust so that C8 and C9 are near their maximum value. With C8 and C9 at minimum value, amplifier may tend to oscillate.

6. Adjust C11 for minimum distortion. Typical distortion AC-101/105 - 0.1%; AC-104 - 0.05%.

7. Set OUTPUT AMPLITUDE controls to zero and REGULATION MODE to VOLTAGE.

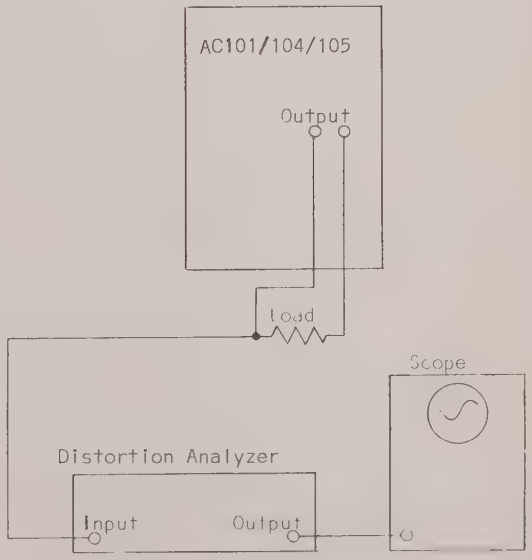


Figure 5-3 Distortion Adjustment Instrumentation

C. OUTPUT TRANSFORMER BALANCE ADJUSTMENT, R-119-R-119b

R-119-119b seldom need adjustment after the initial setting made at Optimation. If necessary, proceed as follows:

1. The REGULATION MODE should still be set to VOLTAGE and 60 ohm load should still be connected, with frequency at 20,000 Hz.

2. Set output amplitude for 104V (AC-101/105) or 110V (AC-104).

3. Adjust R119b (AC-101/105) or R119 (AC-104) for minimum distortion.

4. Set OUTPUT AMPLITUDE controls to zero.

D. HIGH FREQUENCY DISTORTION ADJUSTMENT, 100 kHz (AC-104 only)

1. The REGULATION MODE should be on VOLTAGE, VOLTAGE RANGE 160V/2A, and a 60 ohm load connected.

2. Set frequency to 100 kHz (99,900 Hz).

3. Set OUTPUT AMPLITUDE for 100 V.

4. Retrim C8 and C9 for minimum distortion - typically 0.7%.

5. Recheck distortion at 20,000 Hz under "B", Step 5. If necessary, a compromise setting of C8 and C9 may have to be made to achieve the lowest distortion over the frequency range from 20,000 to 100,000 Hz.

5.2.3 METER CALIBRATION

SYSTEM OUTPUT VOLTAGE

1. Set VOLTAGE RANGE to 160V/2A.

2. Set frequency to 1000 Hz.

3. Set output voltage to 120V and monitor with AC voltmeter having 0.2% or better accuracy.

4. Adjust R92 (Figure 5-2) for 120V reading on amplifier panel meter.

5. Remove AC voltmeter monitor and output leads.

6. Switch VOLTAGE-CURRENT RANGE switch to each VOLTAGE RANGE. Meter on Amplifier should indicate same position on scale within ±2%. This check tests metering resistors mounted on VOLTAGE-CURRENT RANGE switch.

NOTE: The AC-101/104/105 panel meter is intended as a monitor to indicate only the approximate voltage output. Its accuracy at 1000 Hz is ±3%, becoming ±30% at 100 kHz.

AMPLIFIER OUTPUT CURRENT

5. Set VOLTAGE-CURRENT RANGE selector switch to 160V/2A AMPLIFIER DIRECT tap.

6. Connect 60 ohm load.

7. Set output current to 2A and monitor with accurate ammeter (0.5% or better). Use 1000 Hz or 60 Hz, depending on frequency range of ammeter used.

8. Adjust R80 (Figure 5-2) for 2A reading on amplifier panel meter.

5.2.4 OVERLOAD INDICATOR CALIBRATION (AC-101/105 only).

1. Connect matched load to output terminals. Any tap may be utilized as long as the load has the appropriate matched load resistance - or use 160V/2A tap with 60 ohm load.

2. Set frequency to 1000 Hz.

3. Monitor output with distortion analyzer.

4. Increase amplitude above rated output until distortion is about ¼%.

5. Adjust R79 (Figure 5-2) so that overload indicator just fires at this level of distortion.

5.2.5 OVERVOLTAGE PROTECTION CIRCUIT ADJUSTMENT (AC-104/105 only)

LS-101, a light switch, will automatically switch the amplifier to constant VOLTAGE operation if the load is inadvertently disconnected when operating in the constant CURRENT mode. This protect the amplifier. (See Paragraph 4.4.1 e.(2), Page 25 for detailed explanation of operation).

1. Set VOLTAGE-CURRENT RANGE switch to 160V/2A.

2. Turn output REGULATION control to "0" fully counterclockwise.

3. Set the OUTPUT LEVEL VERNIER and STEP control to 0.

4. Set constant CURRENT mode.

5. Set the frequency to 1000 Hz.

6. With no load connected, slowly increase output amplitude to 160V.

   (a) Light switch should operate about this voltage level. They may be ascertained by further increasing the amplitude controls. If the circuit is functioning correctly, the voltage will go through a "knee" - that is, it will rise very little in proportion to further increases in amplitude control adjustment.

7. R175 (Figure 5-2) should be set so that the "knee" occurs at about 160 ±5 volts.

CAUTION

If the "knee" is set at too low a voltage, the amplifier may be unstable when approaching that voltage even if it is properly loaded in the constant CURRENT mode.

SHIPPING DAMAGE

This instrument should be inspected in accordance with instructions in Section II as soon as it is received. If it does not operate or has been damaged in shipment, a claim should be filed with the carrier. A complete report of the damage should be obtained by the claim agent and this report forwarded to Optimation, Inc. If this claim is not filed by you with the carrier, we cannot assist you in recovering the damage claim against the carrier. Upon receiving this report, we will advise you what to do with the instrument and arrange for repair or replacement. Be sure to include model and serial number when referring to this instrument.

WARRANTY

Optimation, Inc. warrants each instrument manufactured by us to be free from defects in material (except vacuum tubes, fuses and lamps) and workmanship. Our obligation under this warranty is limited to adjustment or service of any instrument returned to us for that purpose and replacement of defective parts (except as noted above). This warranty is valid for one year after delivery to the original buyer when the instrument is returned, transportation prepaid, and after our inspection shows to our satisfaction that the instrument is defective. If the defect has been caused by misuse or improper operating conditions, this warranty is invalid. In this case, repairs can be made at a nominal charge, which we will quote before proceeding.

IF ANY DISCREPANCY DEVELOPS, TAKE THE FOLLOWING STEPS:

1. Notify Optimation, Inc., or our authorized representative in your area, giving full details of the problem. Include test data. If the question involves specifications, indicate measuring instruments you used in the test and the method of measurement. When we receive this data, we will send you service data or shipping instructions.

2. When you receive shipping instructions, send the instrument prepaid to us or the authorized repair facility we designate in the instructions.

SHIPMENTS TO OPTIMATION

Shipments to Optimation, Inc. should be made by truck, REA Express, or Air Freight. Utilize the original packing container, if possible. It is expressly designed to ship our products safely. Otherwise, use a "box-within-a-box" with at least three inches of shock absorbent material surrounding the inner box. The instrument must be secure in the inner box and the outer box must be rigid.

Do not ship systems with more than one chassis intact, except via electronic van. Each chassis should be packed individually.

We are confident you will find Optimation instruments excellent and will look forward to any comments or questions you may have with regard to their use or application. May we hear from you?

Thank you.

OPTIMATION, INC.

6.1 OSCILLATOR

REF.	PART NO.	DESCRIPTION
AR1	901181	AMPLITUDE STAB ASY RC04,SYS,H
C3	525040	CAP ELC TUB 10MF-10&150% 50V
C4	525120	CAP ELC TUB 100MF-10&150% 15V
C5	525050	CAP ELC TUB 20MF-10&150% 6V
C6	522150	CAP FIX CER .01MF 20% 1000V
C7	525070	CAP ELC TUB 40MF-10&150% 75V
C8	522150	CAP FIX CER .01MF 20% 1000V
C10	525020	CAP ELC TUB 8MF-10&150% 100V
C11	525800	CAP ELC TLK1500/1500MF10&150%25V
C12	525150	CAP ELC TLK 150MF-10&100% 150V
C13	525800	CAP ELC TLK1500/1500MF10&150%25V
C14	531020	CAP VAR AIR 2.2-34PF JOHNSON
C19	523090	CAP FIX POS .8MF 1% 50V
C1A	523061	CAP FIX POS 0.25MF 1% SEL 50V
C1B	523041	CAP FIX POS 0.025MF 1% SEL 50V
C1C	520301	CAP FIX MIC 2500PF 1% 500V F SEL
C1D	520120	CAP FIX MIC 240PF 1% 500V F
C1E	532020	CAP VAR CER 3-12PF 350V NPO
C28	522200	CAP FIX CER 0.1MF 10%100V
C29	522020	CAP FIX CER 3.3PF
C2A	523101	CAP FIX POS 1MF 1% SEL 50V
C2B	523046	CAP FIX POS 0.1MF 1% SEL 50V
C2C	520501	CAP FIX MIC .01MF 1% 500V F SEL
C2D	520230	CAP FIX MIC 910PF 1% 500V F
C2E	520059	CAP FIX MIC 56PF 1% 500V F
C2F	532040	CAP VAR CER 4.5-25PF 350V NPO
C43	522200	CAP FIX CER 0.1MF 10%100V
C44	522200	CAP FIX CER 0.1MF 10%100V
CR3	544310	ZENER DIODE CD34381 53.5V 5%
CR4	544030	ZENER DIODE IN756A 8.2V 10%
CR5	544300	ZENER DIODE CD34379 6.8V 5%
CR7	543030	DIODE IN625
CR8	543080	DIODE IN3254
CR9	543080	DIODE IN3254
CR10	543080	DIODE IN3254
CR11	543080	DIODE IN3254
CR12	544091	ZENER DIODE 75V
CR13	543050	DIODE IN4719 OR MRA1030A
CR14	543050	DIODE IN4719 OR MRA1030A
CR15	543050	DIODE IN4719 OR MRA1030A
CR16	543050	DIODE IN4719 OR MRA1030A
CR17	543030	DIODE IN625
CR18	543030	DIODE IN625
CR23	544040	ZENER DIODE IN4741A 11V 5%
CR24	543030	DIODE IN625
CR25	543030	DIODE IN625
DS1	551115	LAMP NO. 19 12V MIN 2 PIN
DS2	551115	LAMP NO. 19 12V MIN 2 PIN
DS3	551115	LAMP NO. 19 12V MIN 2 PIN
DS4	551115	LAMP NO. 19 12V MIN 2 PIN
DS5	551115	LAMP NO. 19 12V MIN 2 PIN
DS6	551115	LAMP NO. 19 12V MIN 2 PIN
DS7	551115	LAMP NO. 19 12V MIN 2 PIN
DS8	551115	LAMP NO. 19 12V MIN 2 PIN
DS9	551115	LAMP NO. 19 12V MIN 2 PIN
F1	570120	FUSE SLO BLO .3A 125V 3AG
J2	000076	RCPT 7 PIN FEM AMPH 126-198
Q1	540081	TRANSISTOR 2N3053-1
Q2	540114	TRANSISTOR 2N3250-4
Q3	540170	TRANSISTOR 2N3707
Q4	540120	TRANSISTOR 2N3512
Q5	540081	TRANSISTOR 2N3053-1
Q6	540130	TRANSISTOR 2N3567
Q7	540010	TRANSISTOR 2N669
Q8	540025	TRANSISTOR 2N1183
Q12	540081	TRANSISTOR 2N3053-1
Q13	540140	TRANSISTOR 2N3638
R7	513050	RES VAR WW 50 OHM 20% 2W EX SFT
R8	502020	RES FIX MF 49.9 OHM 1% 1/2W
R9	500030	RES FIX CC 10 OHM 10% 1/4W
R10	511195	RES TRIM WW 5K 20% 2W EXTSCR CTS
R11	502160	RES FIX MF 1.15K OHM 1% 1/2W
R12	502100	RES FIX MF 499 OHM 1% 1/2W
R14	502160	RES FIX MF 1.15K OHM 1% 1/2W
R15	500030	RES FIX CC 10 OHM 10% 1/4W
R16	502190	RES FIX MF 2K OHM 1% 1/2W
R17	511220	RES TRIM WW 10K 1/2W THM SET DAY
R18	502150	RES FIX MF 1.07K OHM 1% 1/8 W
R19	501060	RES FIX DC 25K OHM 1% 1W
R1A	502801	RES FIX MF 31.35K 1% 1/8W GRADED

REF.	PART NO.	DESCRIPTION
R1B	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R1C	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R1D	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R1E	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R1F	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R1G	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R1H	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R1I	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R20	502180	RES FIX MF 1.5K OHM 1% 1/2 W
R21	502100	RES FIX MF 499 OHM 1% 1/2W
R22	502100	RES FIX MF 499 OHM 1% 1/2W
R25	502020	RES FIX MF 49.9 OHM 1% 1/2W
R27	507210	RES FIX WW 324 OHM 1% 1/2W SA10
R28	500120	RES FIX CC 1K OHM 10% 1/2W
R29	502110	RES FIX MF 604 OHM 1% 1/8W
R2A	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R2B	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R2C	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R2D	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R2E	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R2F	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R2G	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R2H	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R2I	502801	RES FIX MF 31.35K 1% 1/8W GRADED
R32	502130	RES FIX MF 1K OHM 1% 1/8W
R34	513140	RES VAR WW 2K OHM 5% 5W FL30A EX
R36	500220	RES FIX CC 15K OHM 5% 1/2W
R37	502060	RES FIX MF 243 OHM 1% 1/2W
R38	502060	RES FIX MF 243 OHM 1% 1/2W
R39	500080	RES FIX CC 470 OHM 10% 1/2W
R3A	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R3B	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R3C	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R3D	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R3E	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R3F	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R3G	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R3H	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R3I	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R40	502131	RES FIX MF 1K OHM 1% 1/2W
R41	502180	RES FIX MF 1.5K OHM 1% 1/2 W
R42	507090	RES FIX WW 17.5 OHM 1% 5W
R44	511220	RES TRIM WW 10K 1/2W THM SET DAY
R45	500080	RES FIX CC 470 OHM 10% 1/2W
R46	502258	RES FIX MFTO 5.1K OHM 2% 1/2W
R47	511220	RES TRIM WW 10K 1/2W THM SET DAY
R48	502258	RES FIX MFTO 5.1K OHM 2% 1/2W
R4A	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R4B	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R4C	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R4D	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R4E	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R4F	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R4G	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R4H	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R4I	502901	RES FIX MF 313.5K 1% 1/8W GRADED
R50	507190	RES FIX WW 237 OHM 1% 1/2W SA10
R51	507170	RES FIX WW 226 OHM 1% 1/2W SA10
R52	507170	RES FIX WW 226 OHM 1% 1/2W SA10
R58	502258	RES FIX MFTO 5.1K OHM 2% 1/2W
R5A	500380	RES FIX CC 1.6M OHM 5% 1/2W
R5B	502680	RES FIX MF 523K OHM 1% 1/8W
R5C	502600	RES FIX MF 261K OHM 1% 1/8W
R5D	502570	RES FIX MF 158K OHM 1% 1/8W
R5E	502550	RES FIX MF 102K OHM 1% 1/8W
R5F	502510	RES FIX MF 75K OHM 1% 1/8W
R5G	502490	RES FIX MF 56.2K OHM 1% 1/8W
R5H	502450	RES FIX MF 44.2K OHM 1% 1/8W
R5I	502650	RES FIX MF 348K OHM 1% 1/8W
R6A	500380	RES FIX CC 1.6M OHM 5% 1/2W
R6B	502680	RES FIX MF 523K OHM 1% 1/8W
R6C	502600	RES FIX MF 261K OHM 1% 1/8W
R6D	502570	RES FIX MF 158K OHM 1% 1/8W
R6E	502550	RES FIX MF 102K OHM 1% 1/8W
R6F	502510	RES FIX MF 75K OHM 1% 1/8W
R6G	502490	RES FIX MF 56.2K OHM 1% 1/8W
R6H	502450	RES FIX MF 44.2K OHM 1% 1/8W
R6I	502650	RES FIX MF 348K OHM 1% 1/8W
R76	506010	RES NON-INDUC 5-OHM 1% 1/2W
R86	500080	RES FIX CC 470 OHM 10% 1/2W